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September - October 1961

GAS TURBINE

THE UNIVERSITY OF TEXAS
SEP 1961
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Gas Turbine In Combined Cycle
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International's Tractor Drive of the Future
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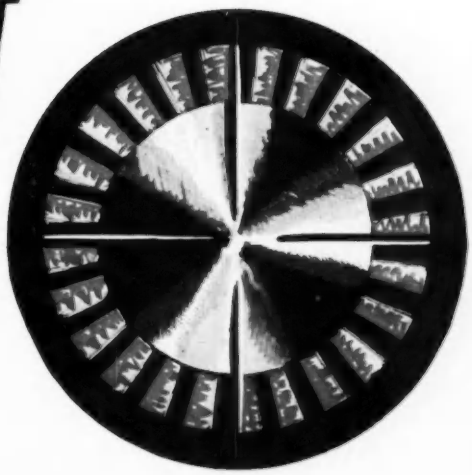
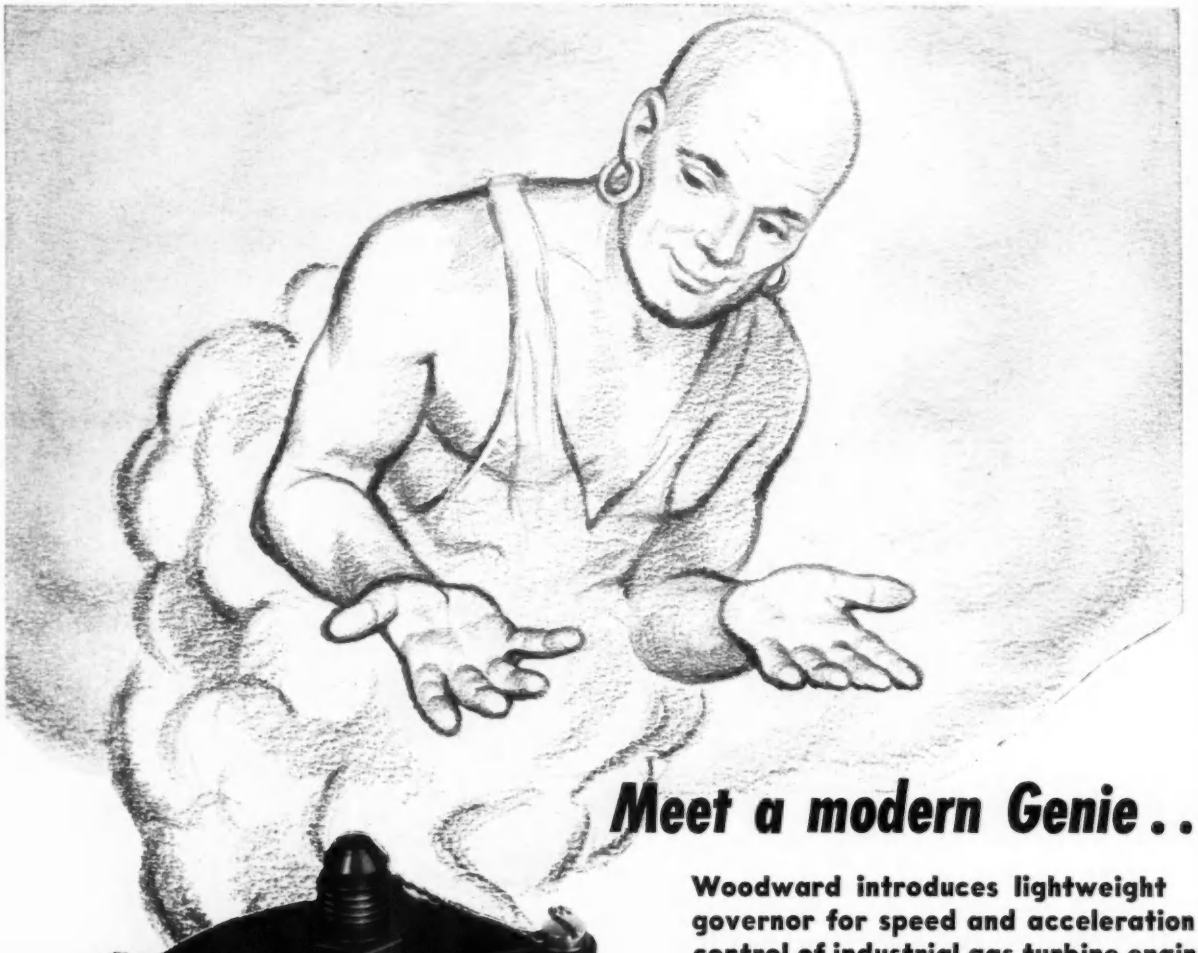


Report on Gas Turbine Controls



Meet a modern Genie . . .

Woodward introduces lightweight governor for speed and acceleration control of industrial gas turbine engines

Aladdin found magic in a lamp. Now Woodward brings you "modern magic" in its new Type 1945 Governor which provides safe, reliable fuel control for 50-500 h.p. gas turbine engines used in industrial applications. It precisely senses speed to establish the correct flow of fuel. An automatically varied restriction prevents the governor from sending too much fuel to the combustion chamber when load increases. An adjustable stop keeps the governing valve from closing completely when a large load decrease occurs. Smoother, more dependable engine operation results. The simple, compact design makes possible low cost, light weight and long life.

You don't need a magic lamp to put this "modern genie" to work on your gas turbine engine — just write for complete information on the Type 1945 Governor today!

WOODWARD GOVERNOR COMPANY,
ROCKFORD, ILLINOIS • Fort Collins, Colorado
Schiphol, The Netherlands • Slough, England
Tokyo, Japan

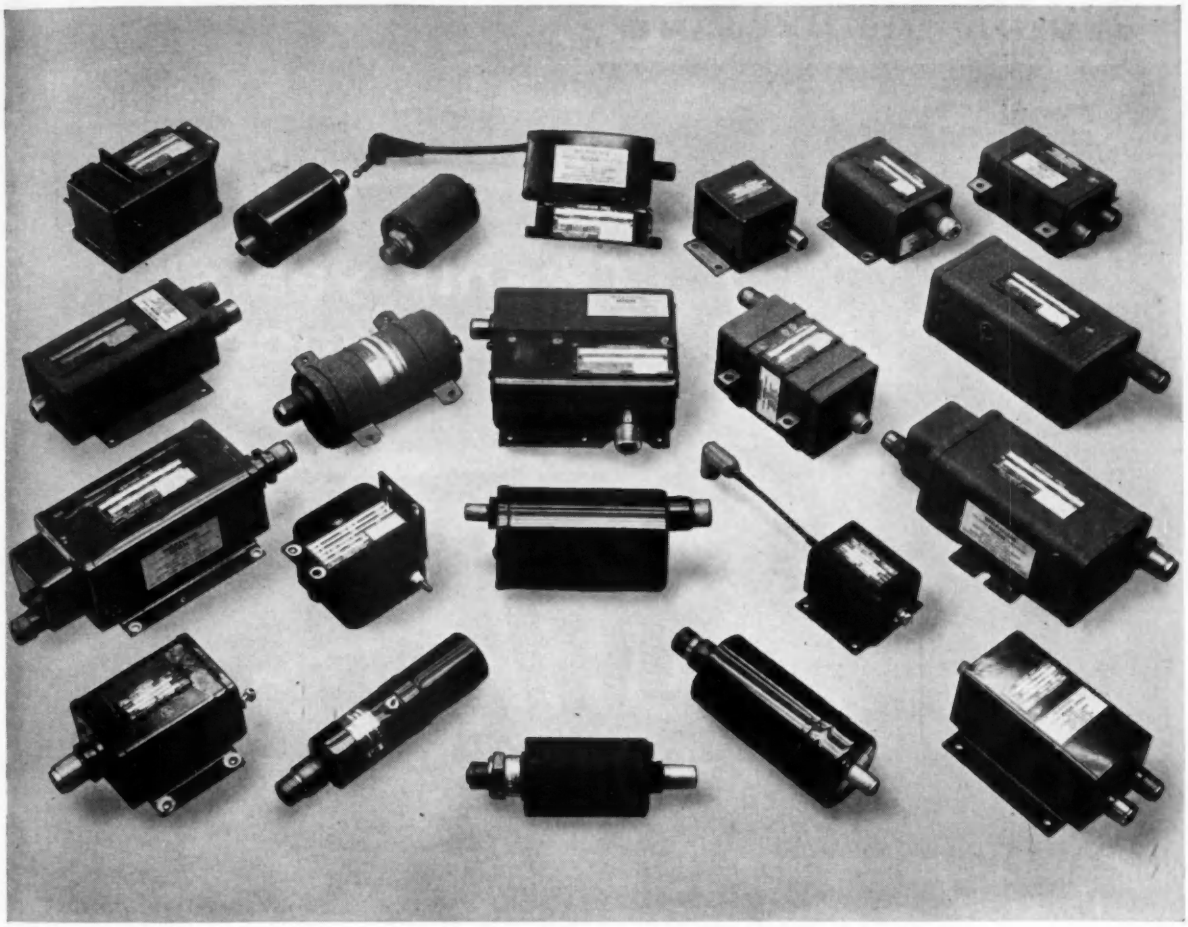
Shown here actual size, Woodward's new Type 1945 Governor is 3" high, 3" in diameter, weighs but 1.6 lbs. and has only 5 moving parts.

WOODWARD SERVICE

"World's oldest and largest manufacturer of prime mover controls exclusively"

S-109

For more information write in No. 901



BENDIX IGNITION EQUIPMENT

Tailored to specific gas turbine needs

You see here some representative members of the large Bendix ignition equipment "family" developed to meet *exact* gas turbine engine requirements.

As specialists for many years in designing and producing ignition equipment of all kinds, the Scintilla Division of Bendix is able to "tailor-make" systems that unerringly combine the ignition characteristics best suited to a particular gas turbine engine.

To round out the ignition "package," we also produce a full range of igniter plugs, cables, electrical wiring harnesses, and electrical connectors.

For ignition equipment that assures full-time efficiency, call us.

Scintilla Division
SIDNEY, NEW YORK

THE Bendix CORPORATION

For more information write in No. 902

BEHIND THE MACHINE

Advanced designs; a wide range of types and sizes; high performance figures; these are the results of over twenty years' experience of design, research and manufacture of gas turbines by AEI engineers.

AEI gas turbines have been installed in aircraft and merchant ships and in frigates and destroyers of the Royal Navy. Industrial machines are suitable for every mechanical drive application as well as power generation, and they have output ratings of 1,750 kW and upwards.

The picture shows work on the rotor of an L21C gas turbine being built for the Basrah Petroleum Co. Larger machines of similar design —the L51C—were recently installed in Iran to supply power for the electrification of the Gach Saran oilfield.

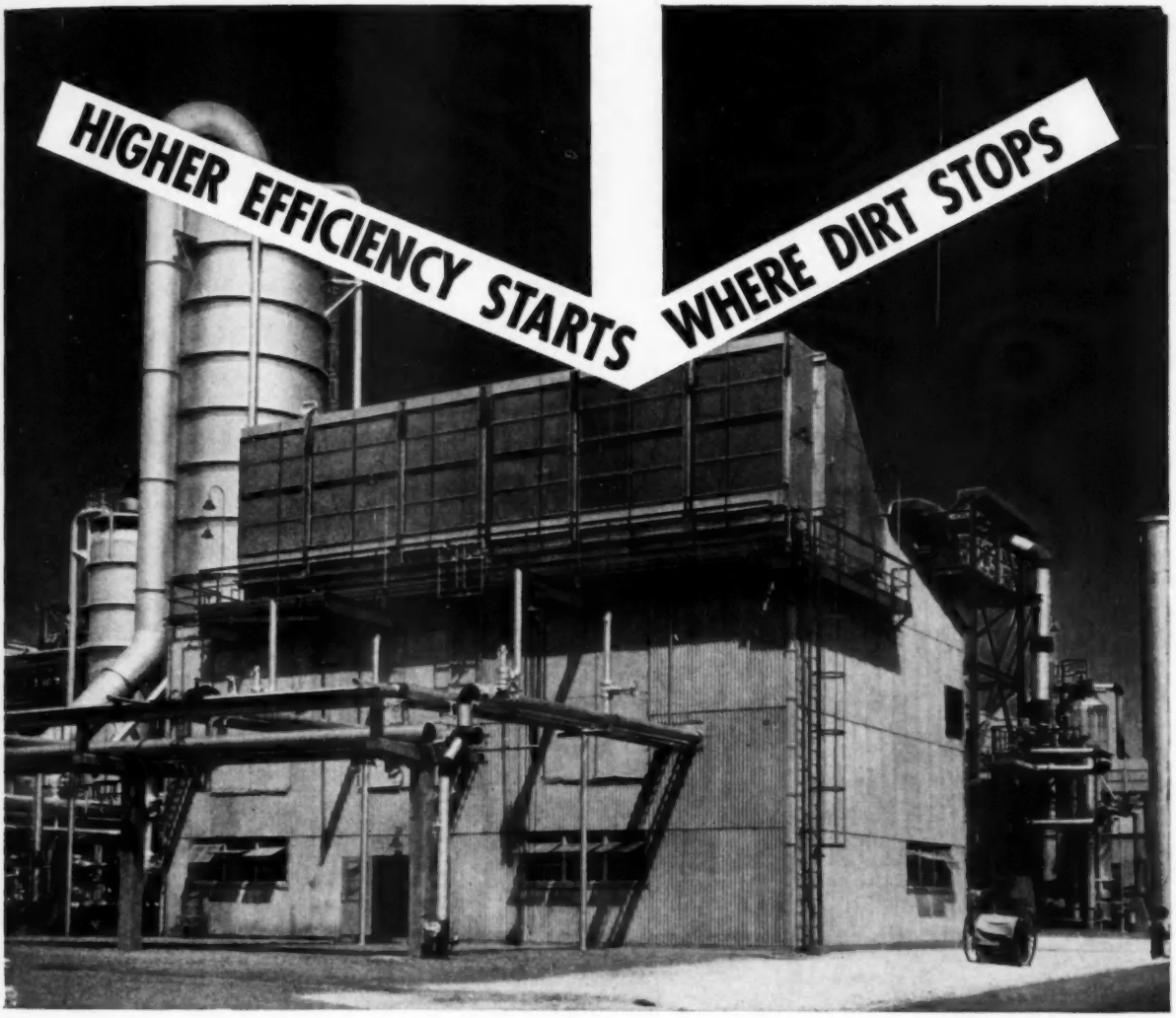
Produced by AEI Turbine-Generator Division, Britain's largest manufacturer of turbine-generators.

AEI Associated Electrical Industries Export Ltd

33 GROSVENOR PLACE, LONDON SW1

B/L003/I

For more information write in No. 903



AAF cleans and cools intake air, helps boost petrochemical output

At Odessa Budadiene Co., Odessa, Texas, they're using the hot exhaust from two gas turbines to regenerate catalysts in the manufacture of budadiene.

A combination of MULTI-DUTY automatic, self-cleaning filters and Amer-Kool evaporative coolers assures clean, cool intake air for both 8500-HP turbines. The automatic intake filters operate continuously, while the evaporative coolers are operated only when ambient temperatures necessitate cooling the air for increased turbine output.

Whether your operation is in a hot and dusty desert, a temperate region, or the Arctic — whether the application is one of process or pumping — whether your station is automatic or attended, portable or stationary — AAF has air filtration equipment *engineered* to match your requirements!

For information on AAF's complete line of BETTER AIR products for engines and compressors, write today for Bulletin 150. Address: Mr. Robert Moore, American Air Filter Co., Inc., 490 Central Ave., Louisville, Kentucky.

AAF **American Air Filter**

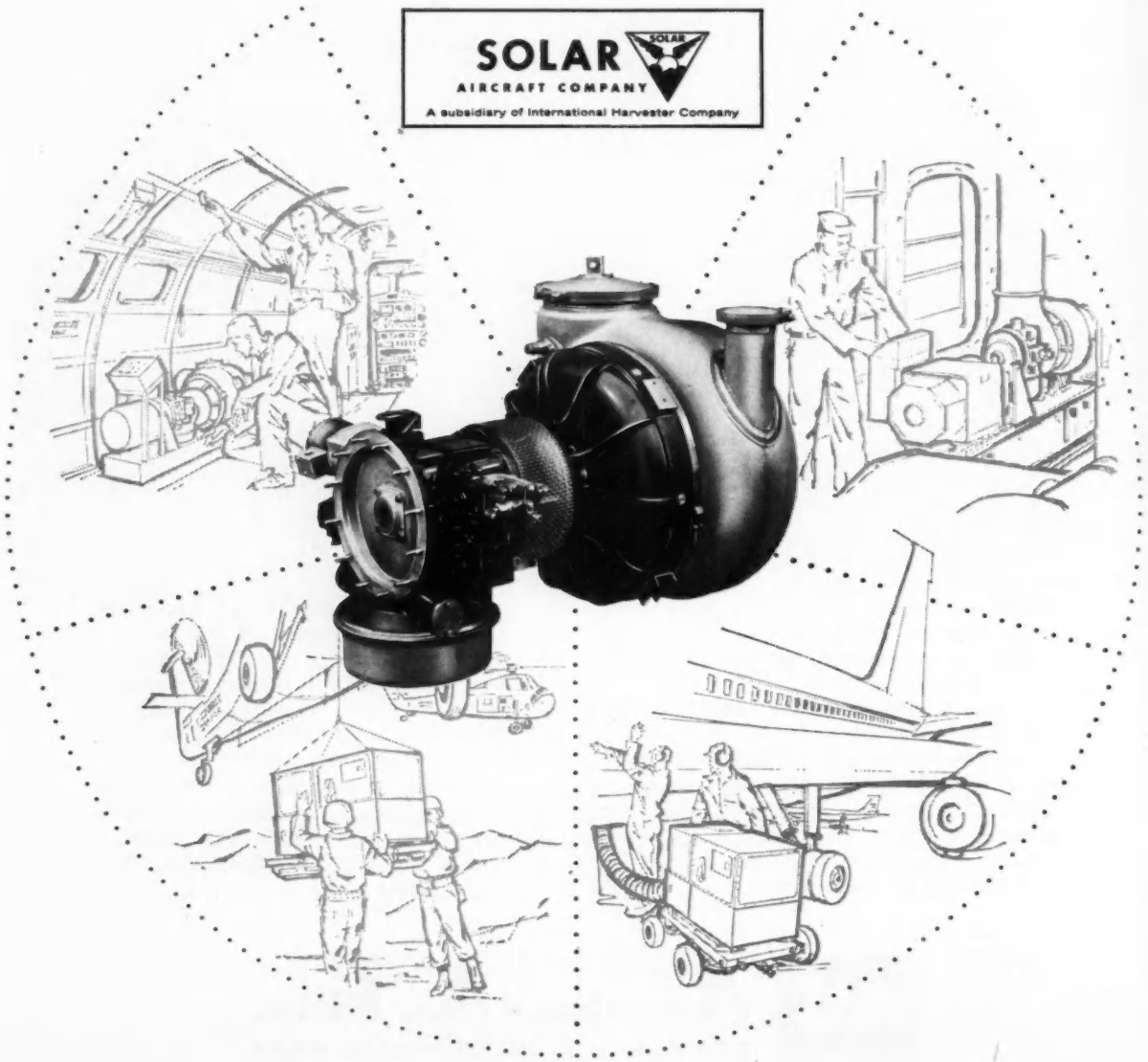
BETTER AIR IS OUR BUSINESS

For more information write in No. 904

The Solar T-350 gas turbine is now in production. It is a rugged, reliable engine ideally suited for aircraft starting and multipurpose auxiliary power applications./ The T-350 can be used for electrical power generation and as a power source for air conditioning, de-icing and hydraulic systems./ The T-350 weighs 195 lbs. In varying configurations, it produces nominal ratings of 350 hp or 235 kw or 130 ppm of air at 54 psia. It is available in a combination of air bleed and shaft power./ Like all Solar gas turbines, it starts instantly, has minimum vibration and is easily maintained. Fuel consumption is low. Write to Dept. J-141, Solar Aircraft Company, San Diego 12, Calif.

Versatile new Solar T-350 gas turbine does more jobs more efficiently

SOLAR
AIRCRAFT COMPANY
A subsidiary of International Harvester Company



For more information write in No. 905

GAS TURBINE

VOLUME 2, No. 5, September-October, 1961

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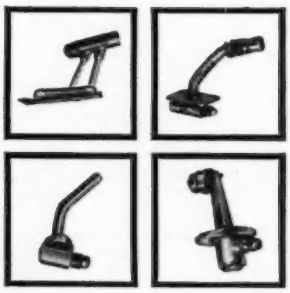
B-58 BREAKS SPEED RECORDS WITH HELP OF BENDIX® FUEL NOZZLES

FLYING A CLOSED COURSE of 1,000 kilometers, a Strategic Air Command Convair B-58 Hustler recently set new world speed records. With full afterburning, the Hustler achieved a top speed of 1,430 mph on its way to a record 1,284.73 average. Each of the Hustler's four General Electric J79-5 engines is fed by 10 Bendix Fuel Nozzles.

Bendix Fuel Nozzles provide dependable fuel delivery to the engines of military and commercial aircraft—answer the more severe problems of cold engine starts and restarts after flameout. Designed and mass-produced to precision standards, they are specified for reliable and economical performance on jet aircraft, missiles, helicopters, and auxiliary power units. Perhaps Bendix nozzles can help solve *your* fueling problems. Write for details.



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ECLIPSE MACHINE DIVISION
ELMIRA, N. Y.

THE Bendix CORPORATION

Export Sales & Service: Bendix International, 205 E. 42nd St., New York 17, N. Y.

For more information write in No. 906

EDITORIALLY SPEAKING

"Wraparound"

"Wraparound" is a total, integrated design concept to provide the best possible equipment performance and efficiency . . . the envelope that takes into consideration the equipment's specific application, compatability of its components, its service and environmental conditions. Often, this wraparound has as its core, the key or critical component on which overall success depends. Groups of engineers assigned this type project join the "Wraparound Club" and today, as in the past, there are many "Chapters". An example from the past and in a different field occurred in the 1920's at GE's Erie Works. A group of engineers headed by John Aydelott undertook to wrap the characteristics of an electric generator around a ruggedly-used traction motor, the whole "wraparound" being a locomotive's efficient electrical drive system.

There have been and are many such "Chapters" in the gas turbine field. And there's always a focus for the "wraparound". One group learned some years ago that in the design of a single-shaft gas turbine-generator set that the gas generator is the key and design of other components including the electric generator must be wrapped around it. A 2-shaft unit is more involved and here the key component is the power turbine; everything else must be wrapped around it.

Today, several groups are working on more complex packages, adding heat exchangers to improve efficiency at part load. Fortunately, this is a worldwide activity and several "Chapters" of the "Club" are contributing to a solution. Communication of results is getting better, one group's partial solutions helping others and spurring them on to a final solution. Books have been written, the one on heat exchangers by Dr. Hryniszak being excellent. Compilations of data are being made. Prof. London of Stanford University, for example is the recipient of data from many groups studying and building gas turbines with integrated heat exchangers. This interest started in the 1940's when Prof. London began to issue studies for the Bureau of Ships on gas turbine heat transfer surfaces.

As a result of the work of all the "Club's Chapters", the "wraparound" of specific designs for specific applications is getting tighter and tighter. Units are getting better and better and the specific "wraparounds" getting so numerous that we'll soon have highly-efficient and competitive gas turbine packages for most applications.

R. Tom Sawyer

From an original painting for CECO by R. T. Handville

GRUMMAN'S AO-1 MOHAWK is powered by two Lycoming T-53 gas turbines, each with complete, single-package *fuel control and pumping system* engineered and precision-produced by Chandler Evans.

CECO's product in the Mohawk is one of a number of "unitized" control systems developed expressly for the fast-growing, small gas turbine field. In addition to controls for application in fixed-wing aircraft, other lightweight, compact CECO engine control systems have been developed for target drones and helicopters.

Chandler Evans *pioneered* single-package design of formerly separate fuel system components, and today enjoys a position of leadership in the field of small gas turbine fuel control and pumping systems.

CHANDLER EVANS CORPORATION • WEST HARTFORD 1, CONNECTICUT

Interesting, informative literature on many CECO products is yours for the asking. Please address your request to Department 41.

CECO® SYSTEMS CONTROLS

For more information write in No. 907

GT HOT LINE

NAVY IS HELICOPTER CONTRACT ADMINISTRATOR . . .

The Navy is now the contract administrator responsible for all of the nation's major helicopter firms. At this time, all major helicopters ordered by the government are powered by gas turbines . . . Navy's responsibility became effective August 1st.

ON-SITE UTILITY "PACKAGES" STIRRING INTEREST . . . AND CONTROVERSY . . .

Interest is building in concept of on-site gas turbine-powered packages to provide electrical power, lighting and by utilizing normally-wasted exhaust heat, to supply heating and/or air conditioning . . . has reached the point where the subject hit the front page of The Wall Street Journal. One early installation was New Park Plaza shopping center in Little Rock, Arkansas . . . another, being built, is at Northern Ilinois Gas Company's headquarters at Glen Ellyn, Illinois. Utilities supplying both electricity and gas face a dilemma . . . gas men want to push on-site units to sell gas; electrical men see possible reduction in electrical energy sales. Some utility executives discount competitive possibilities of the "package"; others are taking a longer look. E. H. Dixon, president of Middle South Utilities, a holding company for several electricity producers, stated, "It's a real competitive threat." Looks good for the gas turbine industry.

ADDITION TO GE'S GROUP IN ENGLAND . . .

Richardson Westgarth (Hartlepool) Ltd., of England, have now joined the General Electric Company group in England . . . They have terminated their gas turbine licensing agreement with Brown Boveri & Company.

GAS TURBINE SALES RISE ON FALLING OVERALL SALES CURVE . . .

Class I railroads in 1960 installed in service 453 new locomotive units compared with 842 in 1959. Of those installed in 1959, only seven were gas-turbine powered. In 1960, the number of gas turbine-powered units rose to 12 . . . Thus, despite a market that fell off by 46%, gas turbine installations rose by 70%. Or, to put it another way, in 1959, gas turbine installations took 0.83% (less than 1%) of a fair market while in 1960 they took 2.65% of a poor one.

PERFECT CIRCLE PURCHASES SCHELLENS . . .

Perfect Circle Corporation has agreed to purchase Schellens True Corp. It will become a wholly-owned subsidiary . . . Schellens produces turbine blades and wheels for use in jet engines and missiles as well as for industrial application . . . Immediate expansion of plant is anticipated since Schellens is currently operating at full capacity.

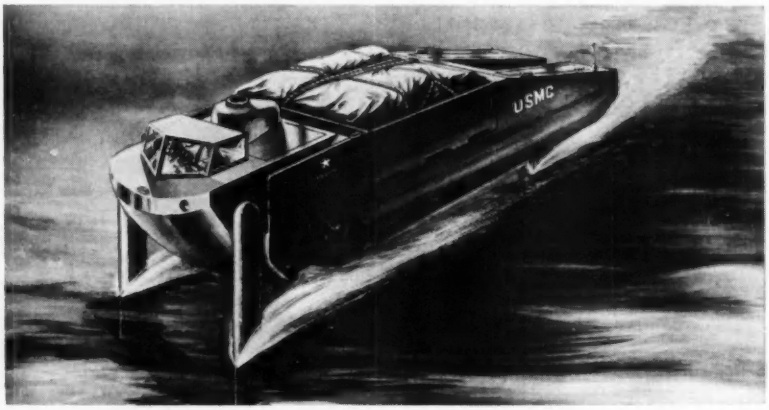
GREENWOOD UTILITIES BUYS GE POWER PACKAGE . . .

The first General Electric gas turbine package power plant to be installed in Mississippi for electric power generation has been purchased by Greenwood Utilities. Unit has 11,250-kw capacity.

GT INDUSTRY NEWS

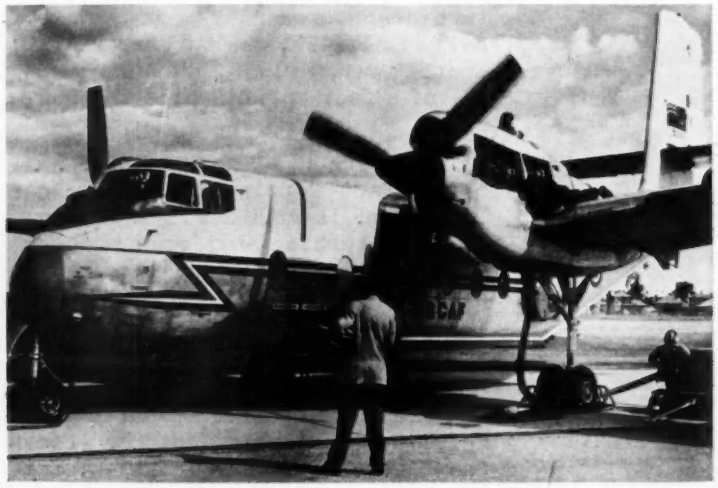
Military Inspects Turboprop Parts

Joint team of Canadian and U.S. military experts inspect Canadian Pratt & Whitney Aircraft's lightweight, 500-hp PT6 turboprop/turboshaft engine parts after official 50-hr Pre-Flight Rating Test. From left, E. L. Smith, Company's Chief projects engineer; Lt-Com. R. J. Barnes, U.S. Navy Bureau of Weapons; W/C W. R. Cole, Royal Canadian Air Force; and C. Stim, U.S. Army Transportation Corps.



LVH, Navy's Newest Amphibian

Artists sketch of the gas turbine-powered LVH acting as a weapons and cargo carrier during an assault operation. Avco's Lycoming Division designed for 45-knot "flying" speed and 25-mph road speed. On land, hydrofoils are retracted completely.



Tie-Down Tests of Turboprops

First run-up of GE's YT64-4 turboprop engines in DeHavilland DHC-4 Caribou flying test bed at Downsview, Ontario plant. Flight testing is scheduled later. Turboprop version of T64 develops 2850 hp with specific fuel consumption of 0.49. Turboshaft configuration is also available for powering helicopters.

Bristol Siddeley Peaking Plant

In a rather complete article on peaking in the Bristol Siddeley Journal, the following interesting comparison of space taken by conventional generating plants appeared.

Plants	Cu ft/MW	Percent
Steam	64,000	100%
Diesel	50,000	78%
Free Piston	21,000	33%
B.S. Gas Turbine	3,400	5.5%

In checking, your figures may be different from the above; however, we believe we can all agree the order of the size of power plants puts the gas turbine as unquestionably the smallest.

Gas Turbines for Office Buildings

Turbines will burn natural gas, according to Northern Illinois Gas Co., to generate all electricity and exhaust heat will generate steam for heating and absorption cooling in some new buildings.

The first building, scheduled for July 1962 completion, will cover 50,000-sq ft and take two turbines of about 300-shp each. The second building, scheduled for completion in January 1963 will cover 125,000-sq ft. Its power will come from several turbines of 300- to 400-shp.

Ni-Gas released the contract to AiResearch.

Gas Turbine Yacht

The 50-knot express yacht *Mercury* has been delivered by Vosper, Ltd. to its owner Mr. Stavros Niarchos. Three Bristol Siddeley marine Proteus gas turbines with free power turbines not only handle the ship at speed but produce all auxiliary power and slow speed maneuvering.

This ship is similar to the "Brave" class of fast patrol boats built for the Royal Navy, also by Vosper, Ltd. This yacht, even though large, would obviously have a speed in excess of 50 knots when we take into account the unusual high horsepower delivered which exceeds a total of 12,000-hp when operating all 3 turbines up to maximum rating. At overhaul time, about 2000 hours of actual operation, one turbine can be easily removed and replaced by another, keeping the yacht in service.

Centrax 600-hp Turbine

For several years Centrax Ltd. of Devon, England has been developing a gas turbine for industrial use. It was recently reported that their first production unit has been put on test and is doing splendidly. This first production unit without a regenerator will be rated 600 hp.

Hound Dog Starters

Contracts totaling over $1.3 million for engine starters for the Air Force missile have been announced by the Garrett Corporation's AiResearch Manufacturing Division, Phoenix, Arizona. Two types of starters for the B-52 carried air-to-air missiles built by North American Aviation are covered in the contracts. These include production quantities of both AiResearch dual solid propellant-pneumatic starters, and pneumatic probe starters.

Delavan

Fuel Injectors

TOUGHER THAN TOUGH JOBS

■ Delavan specialists have broad experience in developing gas turbine fuel injectors that assure a high degree of reliability for long periods of time; that function consistently well under the most rugged conditions.

■ If you have a heavy-duty fuel injection problem consult us. Delavan engineers will develop a fuel injector that's tougher than the toughest job, hardier than the heaviest work. A Delavan injector may well reduce costs, save you valuable time or improve the performance of your equipment.

■ Delavan can bring a fund of developmental experience and manufacturing know-how that is unparalleled in the industry. Delavan is the world's largest manufacturer devoted to the design and manufacture of fuel injectors and spray nozzles.

■ *If an exacting fuel injector for gas turbines is needed . . . so is Delavan. For information write:*

DELAVAN Manufacturing Company
WEST DES MOINES, IOWA

For more information write in No. 908

GT CONTRACTS PROCUREMENTS

Some major gas turbine procurements initiated and contracts awarded during recent months by various agencies of the U.S. Government are listed. This material is from the U.S. Department of Commerce publication "Synopsis of U.S. Government Proposed Procurement, Sales and Contract Awards."

• HQS Aeronautical Systems Division, (LMPMGC) Wright-Patterson AFB, Ohio. J79-GE-11A Turbojet Aircraft Engines with Afterburner, iaw/Contractor's Spec. E-716, 21 June 60, revised 23 Sept. 60, and Amend. No. 1, 28 Dec. 60, (Use: Installations and Spares for F104G Aircraft) and Data. Contract AF 33(600)42761, 28 Feb. 61, 52 ea—$9,411,000—General Electric Company, Flight Propulsion Division, Cincinnati, Ohio.

• HQS Aeronautical Systems Division, (LMPMGC) Wright-Patterson AFB, Ohio. J-79-GE-8 Turbojet Aircraft Engines with Afterburner and related Data. Supplemental Agreement No. 2., 14 Dec. 60, to Contract AF 33(600)41716, 16 ea—$3,360,000—General Electric Company, Flight Propulsion Division, Cincinnati, Ohio.

• HQS Aeronautical Systems Division, (ASKPMG-1) Wright-Patterson AFB, Ohio. J69-T-25 Engines, Data and Summary Bill of Materials, Letter Contract designated Supplemental Agreement No. 3, 6 Apr. 61, to Contract AF 33(600)42426, 69 each—$500,000—Continental Aviation and Engineering Corp., Toledo, Ohio.

• Dept. Navy Bu. Naval Weapons, Washington 25, D. C. One hundred fifty-nine (159) Model J57-P-59W Engines, 13 Model J57-P-20 Engines, 5 J57-P-20 Engines, less Afterburners, and 21 Model J52-P-6 Engines. NOw 61-450-i—$28,471,756—United Aircraft Corp., Pratt & Whitney Aircraft Div., East Hartford, Conn.

• Dept. Navy, Bu. Naval Weapons, Washington 25, D. C. 20 Model J52-P-6 Engines and 10 Model J57-P-20 Engines with Afterburners. NOw 61-450-i, Amend No. 1—$6,588,730—Pratt & Whitney Aircraft Div., East Hartford, Conn.

• Dept. Navy, Bu. Naval Weapons, Washington 25, D. C. 11 Model J57-P-59W Engines. NOw 61-0450-i, Amend No. 2—$1,388,343—Pratt & Whitney Aircraft Div., East Hartford, Conn.

• Dept. Navy, Bu. Naval Weapons, Washington 25, D. C. 3 Model J57-P-19W Engines with Afterburners. NOw 61-450-i, Amend No. 3—$716,517—Pratt & Whitney Aircraft Div., East Hartford, Conn.

• Dept. Navy, Bu. Naval Weapons, Washington 25, D. C. Investigate the turbojet engine combustion paramenter that may be used for automatic actuation of the ignition system within one (1) second after occurrence of engine "flame-out." NOw 61-0579-f—$45,342—The Bendix Corp., Scintilla Div., Sidney, N. Y.

• HQS Aeronautical Systems Division, (ASKPMG-1) Wright-Patterson AFB, Ohio. Starters, Pneumatic, Aircraft Engine, USAF Type STU-1/A; Spare Parts, Aerospace Ground Equip. and Data. (Installations and Spares for USAF and Navy C-130B Aircraft) Letter Contract AF 33-(600)42854, 9 Mar. 61, 212 each—$103,801—The Garrett Corp., AiResearch Manufacturing Co. Phoenix, Ariz.

• HQS Aeronautical Systems Division, (ASKPMG-1) Wright-Patterson AFB, Ohio. J85-GE-5 Turbojet Engine, Contractor's Specification E-1024B, 30 June 60 and Rev. No. 1, 11 July 61, 60 each; J85-GE-7 Turbojet Engine, Contractor's Specification E-1031C, 21 Dec. 59, (GAM-72 Spares) 4 each. Sup. Agreement No. 14, 14 Mar. 61, to Contract AF 33(600)41577—$5,266,400—General Electric Co., Small Aircraft Engine Department, West Lynn, Mass.

• HQS 2709th AF Vehicle Control Group, USAF, Memphis, Tenn. Gear Matched Set Fuel Pump applicable GTC85-71, GTC85-70 Gas Turbine Engines, FSN 2910-651-4709 (Contract AF 40(604)-11553 to RFP 40-604-61-490 and subsequent negotiations thereto) —$45,443—AiResearch Mfg. Co. of Ariz., Div. of Garrett Corp., Phoenix, Ariz.

• Dept. Navy, Bu. Naval Weapons, Washington 25, D. C. Two Model J60-P-3 Engines in accordance with Contractor's Spec. No. A-2412-D. NOw 61-0448-f, No. 4—$127,522—United Aircraft Corp., Pratt & Whitney Aircraft Division, East Hartford, Conn.

INDUSTRY NEWS . . .

H-VW-M to Make G. E. Process Commercially Available

An electrochemical machining process, initially developed by General Electric Company for their jet engine components, is now being readied for extensive commercial use by Hanson-Van Winkle-Munning Company under GE license. The new process is applicable to all metals and will find particular use in machining the modern alloys used in the space and nuclear programs.

The process permits stress-free machining of complex contours in any metal, including the refractory alloys, in a single operation. The process also makes it possible to hold extremely close tolerances (±.0005) at a relatively low capital investment cost.

The ECM process is essentially the reverse of the electroplating. The work piece and a so-called "cutting tool" shaped like the desired part serve as electrodes. In ECM, a high amperage direct current is passed through the work piece to the "cutting tool", through an electrolyte, shaping the raw stock into the finished product.

Coast Guard Testing S-62

A Sikorsky S-62 single turbine amphibious helicopter will be evaluated for 60 days at the Naval Air Test Center, Patuxent River, Md., for possible use by the United States Coast Guard as a search and rescue (SAR) aircraft. It will also be evaluated for shipboard operation aboard a Coast Guard icebreaker, for instrument and night flight and for water and marshy terrain operation.

G. E. Ships First Caravelle VII Engines

General Electric has shipped its first CJ-805-23C aft-turbofan engines to SUD Aviation at Toulouse, France, for Aircraft No. 63, the first Caravelle VII. The engines were shipped from Edwards Flight Test Center where final nacelle fitting and installation of engine accessories and plumbing were accomplished.

Try This On Your Piston Engine

Allison 250-hp gas turbine, YT63-A-3, Component and Accessories Removal Time*:

COMPONENT	Opr.	TIME Min.	Sec.
Power Turbine Governor	R	1	20
Fuel Pump	R	3	01
Starter (Quick Disconnect)	R	0	34
Gas Producer Fuel Control	R	4	57
Fire Shield (Horizontal)	R	2	03
Thermocouple Harness	R	2	40
	I	3	15
Outer Combustion Case	R	11	21
	I	26	24
Turbine	R	5	35
	I	7	02
Fire Shield (Vertical)	R	1	37
	I	1	58
Compressor	R	4	03
	I	4	47

*These times obtained while filming movie to demonstrate time required for removal of the engine components.

R—Removal I—Installation

D-H Steels Now in Production

J. H. Buerger, Jr., Director of Sales at Crucible Steel Company of America, announced that Crucible is now ready to market D-H steels. D-H steels are electric furnace and open hearth specialty steels vacuum treated in the new Dortmund-Horder unit installed at Crucible's Midland Works.

Said Mr. Buerger, "It is our intention to apply only the usual quality extras to those products where such extras exist, even though the D-H process may be applied. Typical qualities requiring no additional premium for D-H processing would be aircraft quality, bearing quality, ball and roller quality, etc. In so doing, Crucible will be passing the improvement in quality obtainable with this process on to its customers without extra charge."

Boeing "Aqua-Jet"

An Allison J-33 jet engine is used to power Boeings 100-mph 38-ft boat that is equipped to hold and test a variety of marine shapes, such as hydrofoils and hulls. The boat is shaped like a catamaran with elaborate metal pinchers in the center space of the boat so these pinchers hold the model when driving it through the water at high speed.

It's a new concept of marine testing which shows promise.

FAA Certifies Modified G-E Turbojet

General Electric has received Federal Aviation Agency Certification for a modification of the CJ-805-3 turbojet, designated the CJ-805-3A.

The 805-3A incorporates highflow provisions in the compressor by increasing the angle of the variable stator vanes. The engine also provides for power setting by the EPR (Engine Pressure Ratio) method. Also included in the modification is the addition of a stator vane feedback reset mechanism which partially closes the inlet guide vanes during thrust reversal, minimizing reingestion of hot gases during reverse thrust operation.

Gas Turbine Generators For Magnetic Minesweeping

Clark Bros. Co., Division of Dresser Industries, Inc., has been designated prime contractor by the U.S. Navy, Bureau of Ships, on a 1.6 million dollar contract to design and build four gas turbine generators for magnetic minesweeping service.

The gas turbines are rated at 1480 kw each and will be geared to d-c pulse generators. They will be installed on minesweepers to supply current to large cables towed behind the ships. The current-carrying cable creates a magnetic field that explodes mines at a safe distance. Each turbine will be mounted directly above the generator and will drive it through a vertical offset speed reducing gear.

GT "COMING UP" REMINDER

SEPTEMBER 11-14 Society of Automotive Engineers, Heavy Duty Vehicle Meeting, including production forum and engineering display, Milwaukee Auditorium, Milwaukee, Wisconsin.

SEPTEMBER 11-15 Instrument Society of America Fall Instrument-Automation Conference and Exhibit and ISA's 16th Annual Meeting, The Biltmore Hotel, Los Angeles, Calif.

SEPTEMBER 24-27 American Society of Mechanical Engineers Petroleum Mechanical Engineering Conference, Muehlebach Hotel, Kansas City, Mo.

SEPTEMBER 24-27 ASME-AIEE National Power Conference, St. Francis Hotel, San Francisco, Calif.

OCTOBER 2-7 Twelfth International Astronautical Congress, Washington, D. C.

OCTOBER 4-6 American Society of Mechanical Engineers Process Industries Conference, Shamrock Hilton Hotel, Houston, Texas.

OCTOBER 9-13 Society of Automotive Engineers, Aerospace Engineering and Manufacturing, including engineering display, The Ambassador, Los Angeles, California.

OCTOBER 9-15 American Rocket Society's 16th Annual Meeting and Space Flight Report to the Nation, Coliseum, New York, N. Y.

OCTOBER 17-19 American Society of Mechanical Engineers and American Society of Lubrication Engineers Lubrication Conference, Morrison Hotel, Chicago, Ill.

OCTOBER 23-24 Joint Meeting, Canadian Aeronautical Institute and Institute of Aeronautical Sciences, Ottawa, Canada.

NOVEMBER 9-10 Society of Automotive Engineers, Fuels and Lubricants Meeting, Shamrock Hotel, Houston, Texas.

NOVEMBER 26-DECEMBER 1 The American Society of Mechanical Engineers Winter Annual Meeting, Statler-Hilton Hotel, New York, N. Y.

Ground Support Contract

A $3 million Army contract for 30-KW gas turbine generator sets for the Sergeant missile has been announced by The Garrett Corporation's AiResearch Manufacturing Division, Phoenix, Arizona.

GT PEOPLE PLANTS PLACES

Snow Heads Solar Office

Robert M. Snow has been appointed turbomachinery sales engineer for **Solar Aircraft Company** in the Detroit, Michigan, area, according to O. M. Sievert, Solar manager of turbomachinery sales.

Snow, whose office is in Detroit, will handle sales activities for Solar's gas turbine engines and related turbomachinery for industrial and military users.

Dr. Darmara Heads New Company

Special Metals, Inc., a new firm which recently purchased the Metals Division of Kelsey-Hayes Co. for $7.7 million, will continue its present line of vacuum induction melted alloys and is planning increases in its production facilities and research. **Dr. F. N. Darmara**, the Metals Division's general manager, who is president of the new company, said the firm will supply vacuum melted products in both vacuum induction and double vacuum melted conditions.

Already a recognized leader in the field, the firm plans to supply a larger product line. It now has an annual capacity of seven million pounds. A 5000-lb furnace, constructed to the company's design at a total cost of more than $1 million, is the largest vacuum induction furnace in the United States.

Arter Boyle Yonker Eberly

Misco Precision Casting Names 3 Sales Mgrs.

K. J. Yonker, Vice President in charge of sales for **Misco Precision Casting Company**, a division of Howe Sound Company, announces the appointment of three separate sales managers to head the newly formed Airfoil Products, Industrial Products, and Special Products divisions, in order to fulfill expanding requirements for Misco's diversified products. They will work with Misco representatives in the field to strengthen services to customers.

Richard W. Arter, with Misco since 1956, has been appointed Sales Manager of Airfoil Products, which will include blades, vanes, buckets, nozzle partitions, etc. of both air and vacuum-melted alloys.

James H. Boyle, who came with Misco in 1959, is Sales Manager of Special Products, which deals with the Vapor Diffusion Department, the Aluminum Investment Casting Department, integral turbine wheels and stators.

Rex Eberly, who joined Misco in 1955, is Sales Manager of Industrial Products, and will be responsible for processing inquiries and orders for the investment casting of parts and accessories.

GE Personnel Changes

Ralph J. Cordiner, Chairman of the Board and chief executive officer of **General Electric Company**, announced the appointment of **Jack S. Parker** as vice president and group executive in charge of the Company's Electronic and Flight Systems Group. Mr. Parker, 43, succeeds Cramer W. LaPierre, newly elected Executive Vice President and director.

William H. Long has been named Manager of the Nuclear Materials and Propulsion Operation at **General Electric's** Flight Propulsion Laboratory Department at Evendale In 1956 Mr. Long was transferred from Evendale to GE's Idaho Test Station as Manager, Test Engineering. He returned to Evendale in 1960 and was Manager of Applications and Contracts prior to this appointment.

Mr. Joseph L. LaMarca has been appointed manager of the newly created International Operation in **General Electric's** Large Jet Engine Department who will be responsible for the exploration and development of applications for the Large Jet Engine Department's military, marine and industrial products outside the continental confines of the United States. This includes the sale of engines, initial sales of product support services, technical assistance, and establishment of overall policies and agreements for international sales.

J. D. Gilbride

New District Manager

Clark Bros. Co., one of the Dresser Industries, Inc., has announced the appointment of **James D. Gilbride** as California District Manager. He will be located in Los Angeles.

In making the announcement, George W. Probst, Vice President of Sales, stated that Gilbride's broad experience in all phases of compressor, engine and gas turbine application would be of particular value in the rapidly expanding Los Angeles area.

Also, Midland Sales and Service Offices and Parts Warehouse of **Clark Bros. Co.**, Division of Dresser Industries, Inc., has been moved into new quarters at 1501 West Industrial Blvd., Midland, Texas.

The move was made to provide expanded facilities.

R. Fletcher

AiResearch Sales Manager-Industrial Gas Turbines

Robert A. Fletcher has been appointed to the newly-created post of Sales Manager—Industrial Gas Turbines. Announcement was made by J. J. O'Brien, Division Manager. This is the second new appointment in the expanding AiResearch industrial gas turbine field to take place in the past four months.

Fletcher joined AiResearch in 1959, having been sales manager of Solar Aircraft Co. of Des Moines, Iowa. He moves to this spot from Supervisor, Fabrication Control at AiResearch Phoenix.

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Water pump with 160-shp pumps 550 gpm at 225 psi. Uses includes hydraulic mining, fire fighting, construction pumping and water flooding operation.

Mission-Packaged Gas Turbine Power

Mission Manufacturing Co. and Garrett's AiResearch Division combine talents to produce gas turbine-powered end-products.

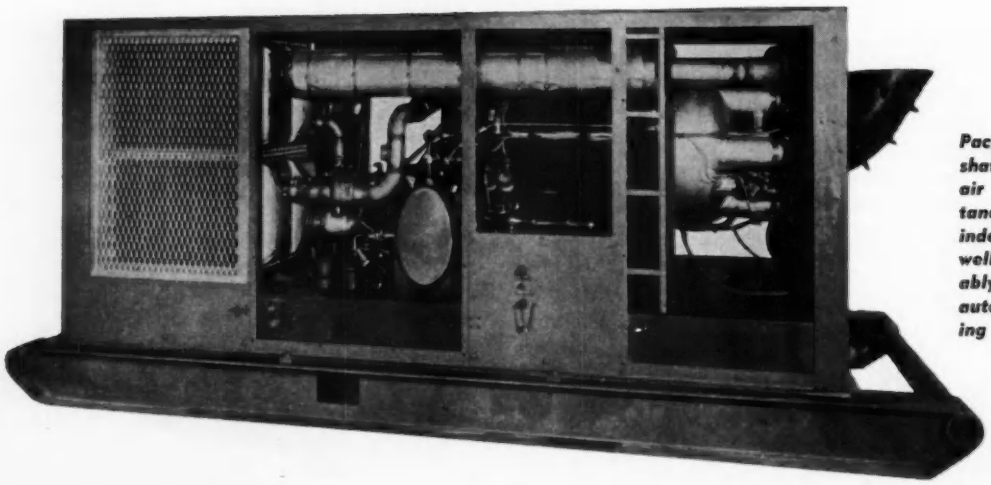
Mission Manufacturing Company is now producing packaged gas turbine power in its ultra-modern Houston plant. This important manufacturer of machinery, tools and equipment for the oil mining industry, as well as for industry in general, is incorporating AiResearch units in these packages.

AiResearch Manufacturing Company of Arizona, a division of the Garrett Corporation, has built more than 10,000 gas turbines of various types. This makes them the largest of the gas turbine manufacturers. Their units in the 35 to 850-hp range are now being packaged and sold by Mission.

Three general types of AiResearch gas turbines are being used. One type supplies energy in the form of compressed air. Another, in the form of shaft horsepower. The third type provides shaft horsepower and compressed air power simultaneously or either form of power independently and interchangeably.

The basic Mission/AiResearch "Round Power Package" consists of the gas turbine compressor and power unit mounted on a skid. The unit is enclosed against weather with heat exchanger, operating controls and safety devices included in the package.

All phases of operation and routine maintenance of



Package provides shaft power and air power simultaneously or either independently as well as interchangably. Control is automatic including start sequence.

Mission's pneumatic Hammerdril drilling granite at rate of 22½ ft per hr. Standard diesel compressor gets 350-psi air boost from air package using AiResearch model 105 gas turbine. Fan clears stone dust at demonstration.

Mission's package are readily accomplished by a single operator even if two or more units are operated together. Units are equipped with a fully-automatic control system which properly sequences starter operation, fuel control and ignition to provide a stable automatic starting cycle. Only a single starting switch is required.

Advantages . . . including versatility

New industrial gas turbine designs are producing fuel economy competitive with conventional power with the added benefits of longer operating life and lower overall costs. They provide a lot of power in a light, compact unit. They start dependably and quickly under conditions of extreme heat or cold, heavy dust or sand. Peak efficiency is obtained in a matter of seconds.

In the range of units built by Mission, 30- to 850-shp, the package can furnish heat at 10,000 to 100,000 Btu per min in free-flowing air up to 950°F or compressed air from 90°F to 500°F. They can also provide large volumes of compressed air at 30 to 350 psig. Yet equipment weight is only 10% that of conventional units. Similarly, they can provide high-pressure, high-volume fluid pumping power with a compact portable unit.

The Garrett Story

The Garret Corporation, AiResearch Phoenix parent firm, is currently celebrating its 25th anniversary. It was founded in 1936 by John Clifford Garrett, who still heads the firm as president and chairman of the board.

Headquartered in Los Angeles, the corporation consists of eight divisions and two subsidiaries located in California, Arizona, New Jersey, Canada and Switzerland.

In 1960, Garrett had combined sales of $224-million, and ranked 232nd among the 500 largest U. S. manufacturers. Garrett pioneered the development and manufacture of aircraft pressurization and air conditioning, from which grew the name "AiResearch". Today Garrett produces more than 2000 varied products.

Development of the first AiResearch gas turbine began in 1946 at Garrett's AiResearch Los Angeles Division. The first unit resembled a suitcase. Its output was 50 hp and it weighed 175 lbs.

AiResearch's gas turbines were originally developed for military applications as an auxiliary power source providing air starts and electrical power for aircraft. They have since been used as portable generators, for air conditioning, snow and ice removal, salvage operations, helicopter propulsion, and ground support equipment by commercial airlines all over the world. Most recently they have been applied to pipeline sandblasting, gas compression, and air drilling.

The Mission Story

In 1925, W. B. Sharp, Jr. organized the Mission Sales Company, with W. T. Campbell and the late Ed Prather as partners. Then Mission's function was to act as sales agents for the Kibele piston, manufactured by the Mission Tool and Supply Company of San Antonio, Texas. The principals had grown up in the oil business and were familiar with its problems. They began first trying to find answers to these problems by designing specialized equipment that would do the job better.

In 1930 the first machine shop was bought by Mission on Railroad Avenue in Houston. Even on its bare earth floor, using cast off machine tools, manufacturing of a high quality was demanded by the founders.

In 1932 the firm was organized into the Mission Manufacturing Company, indicating the increasing importance of manufacturing. By 1935 more space was needed and a nine-acre site on Humble Road in Houston was bought. The shop was big for the Mission of those days, measuring a full 100 x 100-ft. And, a note of luxury crept in: eight private offices. This plant, constantly added to, lasted for more than twenty years until Mission moved to its present plant in 1959. This plant has more than 4½-acres under roof, with a note of added luxury — entire plant is air-conditioned. And there is room for expansion on this 75-acre tract.

Summary

The keynote of expansion for both Garrett and Mission has been versatility—the ability to move in the direction of better products for an expanding market. Garrett's AiResearch Division and Mission complement each other in important respects. AiResearch has the knowhow and facilities for producing the prime movers . . . Mission adds their experience in manufacturing complete end-products, plus their knowledge of and contacts with user markets. This combination can only lead to expanding gas turbine usage.

REPORT ON GAS TURBINE FUEL CONTROL SEMINAR
U.S. ARMY TRANSPORTATION MATERIEL COMMAND
ST. LOUIS, MISSOURI JULY 13, 1961

Helicopter Gas Turbine Controls

What they are • What they do

Reliability requirements, need for broad operational flexibility and environmental extremes call for sophisticated control systems in aircraft applications . . . development builds experience and production for better aircraft as well as industrial gas turbine fuel controls.

Major General William B. Bunker, Commander, USA TMC, made the opening remarks.

SETTING THE STAGE

"My formal, at least, engineering education primarily involves the complex matters of how to build an earth dam. Therefore, my ability to understand some of the more complex pieces of equipment and machinery and phenomena with which we get involved might leave something to be desired.

"As we in the Army start getting into the turbine engine field, the most startling thing to us is that of all its complex gadgets and fans, blow torches and other fans, that the most expensive and the most troublesome device is something that merely is telling us whether the turbine is going and keeps it going.

"Seriously, the cost of (aviation) fuel control is very staggering. If you translate it into terms of construction, the fuel control for a few hundred horsepower would cost more than a fully furnished 5-bedroom house . . . is somewhat less reliable and dependable than the house, and certainly it has a considerably shorter life.

"Therefore, sometimes I suggest to you, Colonel Rogers, (Director, Engineering) that we ought to have an exploration of these sophisticated gadgetries. We ought to review our problems with them, and we ought to understand and conduct an agressive program so that this device doesn't eat us out of house and home. Because with the people with whom we have to do our day-to-day business in the budgeting areas and others, it is rather difficult to get enough money for what, in their minds at least, is nothing more than a carburetor.

"We appreciate the time of our guest lecturers who are going to convince us that these things are not (a) expensive, (b) that they are very reliable, and (c) present no problem . . . and educate us generally in the area of fuel control and governing of turbine engines."

Helicopter Fuel System Governing and Control — A General Picture

Frank Mock, Bendix Products Div., Bendix Corp.

It seems to me that it was a particularly wise step to have this meeting at this time. We are not only starting broad use of new power plants on vehicles that are admittedly difficult to handle: We are also on the threshold, we hope, of a whole new type of airplane, VTOL or STOL in some form or another, that could have tremendous usefulness in both military and civil fields. In their development these same control problems will probably be encountered.

The control may seem a rather insignificant thing for all this attention but it is the element that makes the machine part of the pilot. I have been a bit disturbed, therefore, by the differences which apparently exist between the various devices to be described here today, all of which are proposed for simultaneous use by our Army.

It is perhaps too much to hope that they can be simplified and standardized at this time. It took some years to achieve this with our jet engine controls. Nevertheless, this meeting should be a good start.

Overall duties of power control for a direct air lift device may be listed as follows:

A. *Method of Power Demand*

Elements involved in handling power selection and power demand are shown schematically and only in general form in Fig. 1. They include chiefly a Collective Pitch Control, which establishes the power level; also, a fuel control valve, responsive in some way and at one time or another to gas producer speed and to rotor and power turbine speed.

Thus far, experience seems to have shown that a satisfactory control for level flight at constant speed, and also for hovering, can be obtained with a pilot's manual operation of the Collective Pitch Control while the rotor is kept at constant speed by a fuel governor driven from the power turbine and rotor gear train. This seems also the most simple mode of control, provided it can be made to "accelerate" properly. Suitable modifications are needed for starting up and for ramp idle.

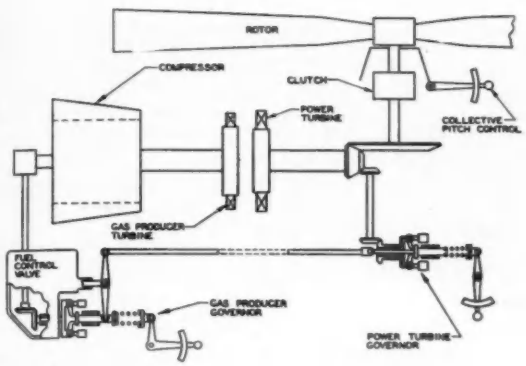


Figure 1

These may be connected up in a number of ways and can include a maximum speed limiter for the gas producer.

It may be opportune here to point out a few differences between the gas turbine and piston engine for helicopter duty. Unlike the piston engine, the gas producer is only "gas coupled" to the rotor. Generally speaking, it does not know what the rotor and power turbine are doing. See Fig. 2. At a given speed, the gas producer has only one fuel and one air consumption, regardless whether the power turbine is running full speed or standing still. Similarly, if the pilot suddenly changes the Collective Pitch Control, it has no direct effect on gas producer speed.

Fig. 3 shows that the torque of the gas turbine rises as the rotor is slowed down, which does not occur to anywhere near the same extent with the piston engine.

B. *Control of Power Supply.*

To hold turbine gas temperature within safe limits while demanding more power, it was necessary to open up the fuel control in proportion to engine speed increase. If the pilot opened the fuel throttle too far at low speed, the turbine temperature went much too high with possibility of blow-out.

Conversely, if while the engine was at high speed he closed the fuel throttle back to idle, the poor little flame would die out under the high draft through the combustor. To cure these conditions, it was desirable for the fuel control to schedule definite fuel flow limits both on accelerating from idle to full speed and when decelerating back from full speed to idle.

C. *Proper Response to Power Demand Change*

We know that the gas producer will accelerate fairly rapidly from above perhaps 85% speed when the governor setting is fully and quickly advanced. This can probably take care of take-off. A more difficult problem is that of rapid power response if, when gliding to a landing in auto-rotation, it is necessary to suddenly increase the collective pitch.

The sudden load will tend to slow down the rotor. The gas producer is at reduced speed and the fuel governor may not open the fuel valve to full wide-open position until there has been an appreciable loss in rotor speed and thrust. Once the rotor has lost speed it will take several seconds to make it up again.

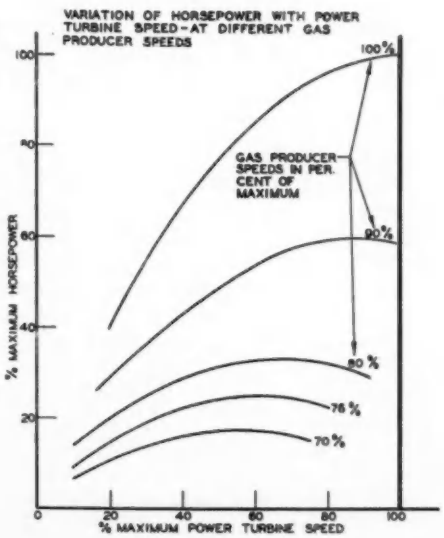
Dealing with this by the governor is a difficulty appreciated most by the governor specialists . . . how difficult it is to make a governor that will respond delicately and accurately at fixed pitch yet at the same time be able to open the fuel valve wide-open on the first sign of decreasing rotor speed.

D. *Precautionary Limitations*

Limitations must be provided against overspeed or overtemperature; against shaft overstress; against dangerous vibration frequencies; etc. Engineers of our industry have well-developed practice to deal with each of these.

It should be emphasized here that the helicopter yields to no aircraft in its requirement for smooth, positive, reliable action of its power control. *This is something on which we dare not cut quality nor expense.*

It is suggested that consideration be given to formulation of specifications that will ensure specific attention to this type of aircraft and assist early development of a satisfactory solution for all the different models that will be used by our Armed Forces.



◀ **Figure 2**

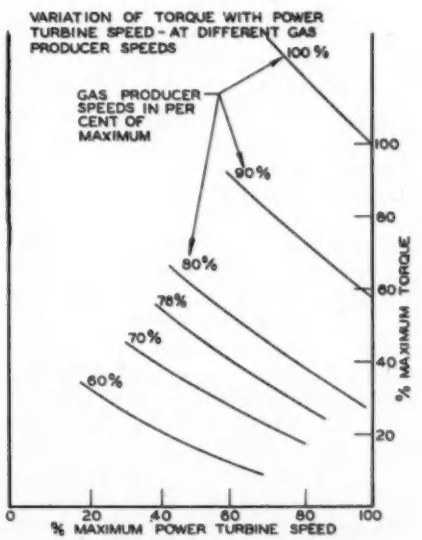


Figure 3 ▶

Allison's T63 with Bendix Products Controls

R. J. Wente, Allison Division, GM

In the early part of the T63 program, Allison conducted a competition among six different control manufacturers. Following this, we ended up with three control manufacturers and actually analogged, built equipment, bench-tested, and operated on the engine products of these three. Finally, we selected the Bendix control for our T63 engine. (Figs. 1 & 2)

The Bendix control is a mechanical-hydraulic-pneumatic system. Basic parameters that we selected for the engine are, (1) the gas producer and power turbine, (2) the ambient temperature compensation requirement and (3) compressor discharge pressure. All work of the computer is done outside of the fuel system. We feel this has several advantages, a principal one being that only one intelligence goes into the fuel system to the throttle.

Fuel System Section

Inside the fuel system section is the maximum-pressure release valve, a pressure regulating valve, the throttle valve, and the cut-off valve. Fuel enters the high-pressure system going past the pressure release valve, past the throttle, and through the cut-off valve.

To get the fuel flow desired, we maintain a constant pressure drop across the throttling valve. This is a function of the pressure prior to throttling and the pressure after the throttle. These are related across the diaphragm with a spring so that we maintain a constant pressure at the throttle. Therefore, the area and the pressure drop determine the flow. This makes the flow proportional to the area since the pressure drop is held constant.

This pressure drop is adjustable externally either up or down. This gives us an adjustment for the specific gravity of the fuel.

Control

During engine starting, the gas producer and power turbine are both at zero rpm. As speed of the gas producer reaches a predetermined value, its governor's flyweights will overcome the preset of its spring, causing its orifice to open slightly. As that orifice opens, the pressure changes in order to collapse a bellows in the system which, in turn, adds more fuel.

The power turbine governor is quite similar to the gas producer governor in its mechanism and its speed orifice.

In starting, the system would first be in the cut-off position which would permit energizing the starter. When the engine reached approximately 10,000 rpm, ignition would be thrown on with a separate manual switch. The throttle and the cut-off valve would be opened. The throttle lever could then be moved up to the idle position or to the 100% condition and the engine would come up to and operate with a power consistant with the collective pitch lever setting.

Fig. 3 is a composite plot of general operation. With the gas producer lever set for 100% and the power turbine governor lever set for 100% and the collective

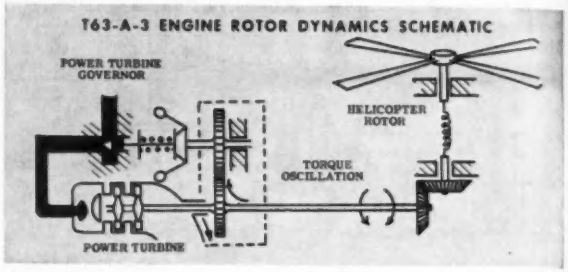


Figure 1

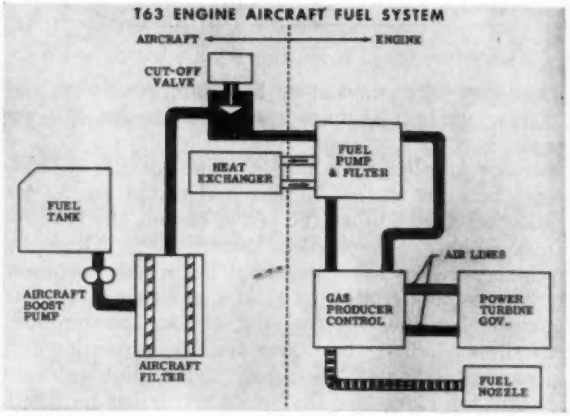


Figure 2

pitch lever at minimum setting, we would have a maximum power turbine speed of approximately 103%. We would have the minimum fuel flow, the minimum gas producer speed, and, of course, the minimum shaft horsepower.

As the collective pitch lever setting is increased, calling for more load to the rotor head, the first thing that happens is that power turbine speed will be reduced slightly. This, in turn, will reset the gas producer governor to cause an increase in fuel flow. This will result in an increase in gas producer rpm and shaft horsepower. Similarly, moving to maximum power requirement will bring the engine down to 100% rpm. Then fuel flow will be 100%. The gas producer output will be nearly 100%, and the shaft horsepower will be maximum.

Compressor Surge Control

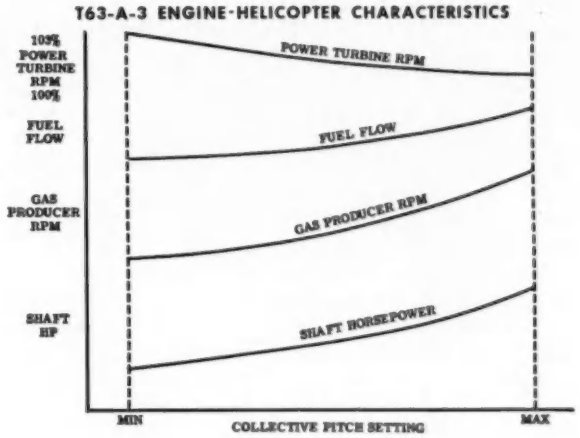
Even though the fuel control does its best to prevent compressor surge, a separate control is required. This opens up a compressor bleed that prevents this condition when the fuel control is unable to do so. When the engine is not operating, this valve is in open position. Then, when a certain compressor pressure ratio is reached, pressure build-up forces the bleed valve against its seat.

On this particular engine we don't pay too high a penalty for compressor bleed air. Whenever you bleed to prevent surging, you get a combination of effects. First, the compressor bleed part is work thrown away. You also reduce the compressor work by reducing pressure but, at the same time, you have less air going

through the turbine. Therefore, turbine temperature runs a little bit higher.

So you have a "pro" and "con" balance on the turbine too. The question is how much you lose between lower air flow and how much you gain between higher turbine temperature. Net change of power at the bleed-operating point is very small, maybe from 5 to 10 hp.

Figure 3 ▶



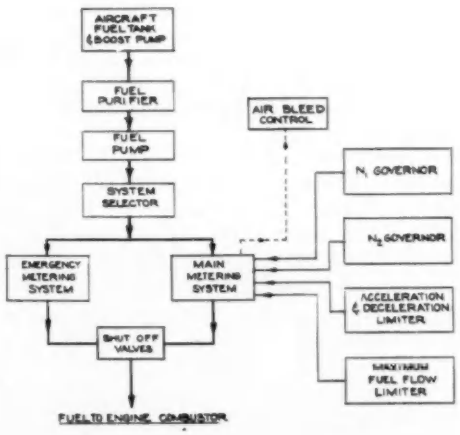
Floyd Boyer, head of the Allison Division mechanical design section in the fuel controls and Mr. Stefneza, Chief Engineer of Bendix were also present and available to answer questions that arose.—Ed.

Lycoming's T55 with Hamilton Standard Controls

H. North, Senior Development Engineer, Gas Turbine Dept., Lycoming

The T55 engine is the second of Lycoming's growing family of free power turbine-type aircraft engines. This engine is currently in production for the Vertol HC1B Chinook helicopter with a 2200-hp rating. The T55-L-5 engine as used in the Chinook is designed to operate in the altitude range of sea level to 25,000 ft, with air speeds from 0 to 300 knots, at ambient temperatures from −65°F up to 130°F and with fuel temperatures ranging from −65°F to 110°F.

In the process of selecting a power control for the T55 engine, consideration had been given to use of pneumatic, electric and hydro-mechanical type fuel controls. After competition among all control manufacturers, a hydro-mechanical type produced by Hamilton Standard was selected. Operation of this control can best be explained with the aid of a simplified block diagram schematic (Fig. 1).



T55 ENGINE FUEL CONTROL

Figure 1

Fuel Flow

In operation, fuel from the aircraft fuel tanks and boost pumps is delivered to the engine inlet where it enters a fuel purifier.

Function of the fuel purifier is to remove contaminants present in the fuel delivered from the aircraft fuel tanks. These might otherwise damage the fuel control system. The fuel purifier is essentially an engine-driven centrifuge wherein fuel is passed through a rotating drum in which heavier contaminants are centrifuged to the outside of the drum and trapped in cavities there. At periodic intervals the purifier is partially disassembled and the accumulated contaminant load is removed from the cavities. After having been cleansed by the purifier, fuel is delivered to the engine fuel pump.

A small screen is provided before the pump gear elements to protect them against any large particles which might find their way through the fuel purifier. A dual-element gear pump is provided to achieve a high degree of reliability and operates so that in the event a single element should fail, the remaining element can continue to pump and provide all the fuel required for starting the engine and for operation up to and including full military power.

Fuel from the fuel pump is then delivered through a second screen filter assembly which removes small chips or shavings which might be generated as a result of fuel pump wear. Fuel then proceeds to the fuel system selector valve which selects either the emergency system or the automatic system of operation.

Control Details

With the automatic system of operation, fuel flows to the main metering system and to the shutoff valve from which it is delivered to the engine combustion chamber. The main metering system consists of a main metering valve and differential pressure regulator. Position of the main metering valve can be controlled di-

rectly by the N_1 governor, by the N_2 governor, by the acceleration/deceleration limiter or by the maximum fuel limiter.

The N_1 governor is biased by compressor discharge pressure and engine inlet air temperature. This accurately compensates for effects of altitude pressure and temperature on the operation of the N_1 governor and enables it to hold maximum gas producer rotor speed at such a level that maximum turbine inlet temperature is accurately limited.

The N_2 or power turbine speed governor is, like the N_1, a droop-type flyball governor. It has a selector lever to permit manual selection of the governed power turbine speed. The N_2 is biased by compressor discharge pressure to compensate for effects of altitude pressure.

The acceleration limiter sets maximum fuel flow that can be introduced in the combustion chamber during accelerations. It is biased by gas producer rotor speed, compressor discharge pressure and inlet air temperature, functioning to avoid surging of the compressor or overtemperature of the turbines during accelerations.

The deceleration limiter is biased by compressor discharge pressure so as to provide what is essentially a minimum fuel/air ratio of the combustion chamber required to avoid loss of combustion fire during deceleration operation.

The maximum flow limiter is provided to limit the absolute maximum fuel flow ever delivered to the engine. It thus limits the absolute maximum horsepower the engine will ever produce.

The air bleed is used during accelerations to improve surge characteristics of the compressor and thus permit faster engine accelerations. Functioning of the control is such that during accelerations up to full power, the air bleed is kept open. During steady-state operation above 30% normal rated power up to full power, the air bleed is kept shut. This optimizes engine fuel consumption, holding it to the lowest level possible.

Goal—Accuracy and Reliability

On the T55 engine the acceleration schedule limiter accuracy is ± 2½% in the critical surge region. This accuracy must be achieved not only on a new control but on one that has achieved 1000 hours of service operation. Further, accuracy must be maintained over operating conditions including an altitude pressure range of sea level to 25,000 feet on helicopters and sea level to 40,000 feet for turboprop engines.

The factor of power control reliability *cannot be too strongly emphasized*. The military services have recognized that reliability of the engine is no better than the reliability of the power control and have required special reliability analysis to be made of the power control before the engine is qualified for production and service usage.

A report issued by the National Aeronautics Space Administration No. RS-54 summarizes experience of the services over a period of years with aircraft gas turbine engines. This report indicates that of all aircraft accidents due to engine failures, about a third were due to malfunction of the power control. Only a minor fraction of these control difficulties were due to functional limitations of the power control and the remainder were due to component failures in the power control.

The reliability aspect of the power control has been strongly highlighted by both Hamilton Standard and Lycoming in the entire development program. No single incident of power control malfunction or difficulty during more than 8000 hours of engine operation and 13,000 hours of bench testing of the control has failed to receive immediate attention and investigation followed by corrective action.

It is believed today that the T55 power control is close to the level of reliability and accuracy required for this application. Continuing effort will be exerted in the future to further improve the reliability and accuracy and substantially reduce the cost of the power control in production quantities.

Lycoming's T53 with Chandler Evans Controls

M. J. Leff, Development Engineer, Gas turbine Dept., Lycoming

THE T53 FAMILY of engines are turbine powerplants employing a free-type power turbine to drive the output shaft. The power turbine is entirely independent of the gas producer. These two sections are controlled by a hydromechanical fuel control built by Chandler Evans. The T53 in its various forms is presently used in a series of applications, including the Bell HU-1 helicopter, the Grumman AO-1 turboprop and the Kaman H43B helicopter. Various engine models cover at present a maximum range from 860 to 1100 shp.

Fuel Flow

Fig. 1 shows the complete automatic system. Fuel, supplied to the engine fuel system from the aircraft system, enters the fuel control and is initially routed to a 200-mesh strainer. After the strainer, the fuel enters a dual-element, gear-type fuel pump. The high-pressure fuel is again strained by a 100-mesh strainer and is delivered to the main metering valve. Pressure drop across the main metering valve is held constant by the main pressure regulating valve. Excess fuel bypasses back to the pump inlet.

The main metering valve receives its signal from the computer section that will be described later. Fuel passes through the main metering valve, then reaches the pressurizing valve. This valve assures sufficient pressure at all times for the servos in the control.

Just before leaving the fuel control, fuel passes through a shutoff valve. A dump valve, mechanically linked with the shutoff valve to the power lever, relieves pressure in the system during shutoff. The dump valve is essentially a bypass-type valve, bypassing fuel back to the fuel pump inlet. Once leaving the fuel control, fuel then enters the main engine manifold and is distributed in the combustion chamber of this turbine by vaporizing-type tubes.

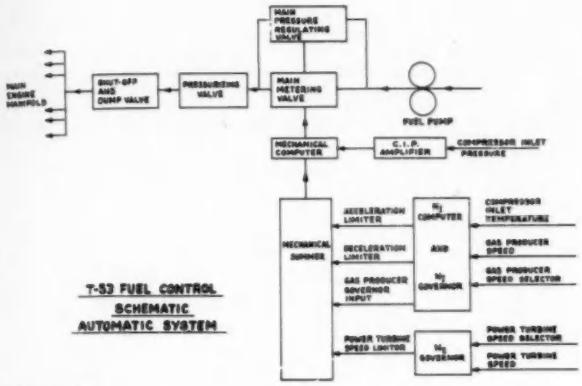


Figure 1

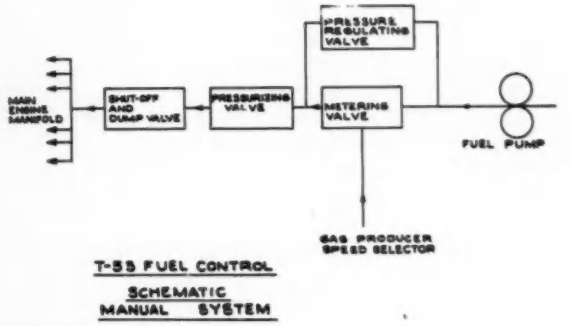


Figure 2

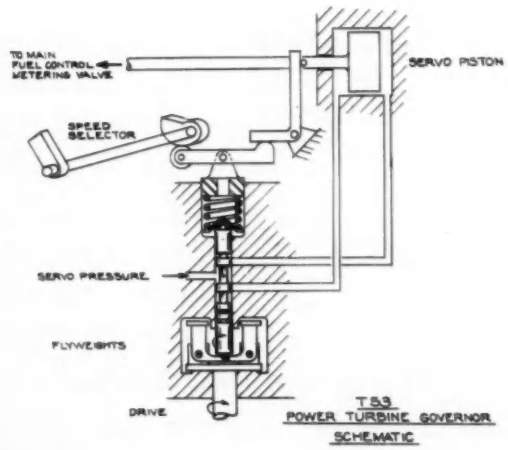


Figure 3

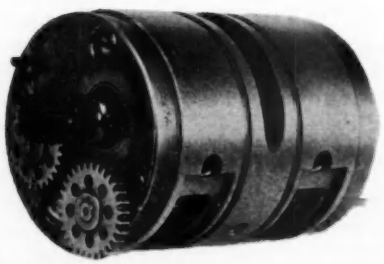


Fig. 4 Dual-element pump cartridge.

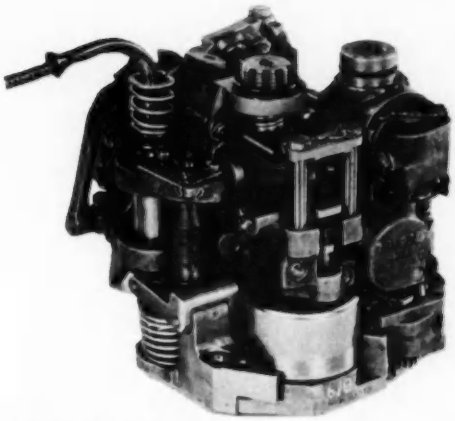


Fig. 5 Computer assembly.

Controlling Fuel Flow

The signal that positions the main metering valve is generated in a computer that senses compressor inlet temperature, compressor inlet pressure, gas producer turbine speed, gas producer speed selector position, power turbine speed and speed selector position.

Data on compressor inlet temperature, gas producer speed and gas producer speed selector position are combined, using a 3-dimensional cam, in the N_1 computer and governor unit. Power turbine speed and power turbine speed selector position are transformed into a power turbine speed limit in the N_2 governor, that will be described in detail later.

Output of the N_1 and N_2 units consists of four limits as shown in Fig. 1 that are combined in the summer such that, with one exception, the one calling for the lowest fuel flow takes precedent. The exception is the deceleration flow. The summer output signal is then biased by the last input, compressor inlet pressure, and is fed to the main metering valve.

External adjustments are available to trim maximum and idle speed and to set acceleration rates. These are particularly valuable when it becomes necessary to replace components in the field. A maximum fuel flow adjustment is also available.

A simplified manual control (Fig. 2) is provided for use in event of malfunction of any component in the primary control. Switchover from automatic to manual control is accompanied with a pilot-actuated switch. The manual control, integral with the main control package, has its own metering valve and a regulating valve that maintains a constant pressure differential across the metering valve. This metering valve is essentially a fine needle valve that will regulate fuel flow to the engine with pilot monitoring.

During helicopter operations, the power turbine governor (Fig. 3) is used for primary control of the aircraft. In operation, after a start is made, the gas producer selector lever is kept at maximum power position and control is effected through the power turbine governor. The power turbine governor speed selector and aircraft collective pitch control are linked together with a cam and can be actuated by the motion of a single lever. In this way, a constant rotor rpm is maintained, regardless of power level, and any load change

is instantaneously signaled to the fuel control for fastest response. This helps in reducing speed undershoot and speed overshoot during transients.

The pump cartridge (Fig. 4) is a dual-element gear-type pump. As you can see from its appearance, it is compact and its removal will not affect control settings.

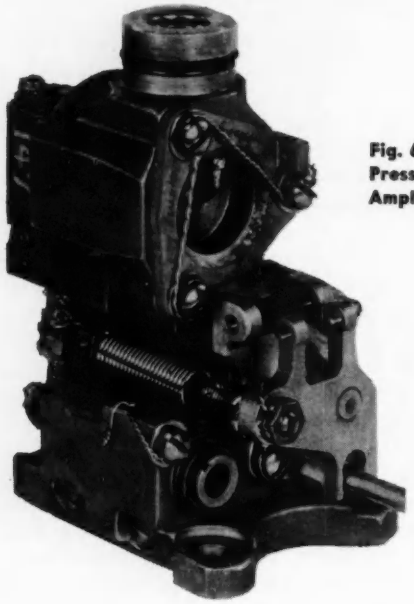


Fig. 6 Pressure Amplifier

The computer assembly (Fig. 5) is required to integrate several inputs very accurately to ultimately end up with a reliable and accurate schedule. Towards this end, servo-operated pistons operating at high force levels are utilized on all speed and pressure signals. The assembly includes a pressure amplifier, the temperature unit and the 3-dimensional cam.

Fig. 6 shows the pressure amplifier. By utilizing high forces, sliding parts are insensitive to friction and contaminants. All low force-level pilot valves are rotated to eliminate friction effects.

Extensive Development and Testing Needed

During development of a fuel control system, extensive laboratory and engine tests must be run. These tests include testing the fuel controls over 100 different scheduled for accuracy, repeatability, and absolute value of schedule. Dynamic as well as static tests are made on the governors and regulating valve systems. Testing is carried on at all ambient temperatures, pressures, and at various fuel inlet pressure conditions.

The pump is tested for its ability to operate with high vapor/liquid ratio, to lift fuel in case of malfunction of the airframe pump and to deliver fuel against high pressures.

The control is subjected to vibration tests in order to prove that the springs, bellows, and other components in the control system can tolerate the expected engine vibrations.

Environmental tests are run with fuel heavily contaminated with solids and liquids. All of these tests are culminated in a 450-hr bench qualification test and a 150-hr engine test which are run according to MIL-E-8595. Upon completion of these rigorous tests, the fuel control parameters will have been operated at extremes of fuel, ambient temperature and with heavy fuel contamination.

This test represents the type of operation that a fuel control might see in service in over 1500 hours of operation. Upon completion of this milestone, a fuel control system is ready for production and still testing continues.

It has been apparent that the control must be considered an integral part of the engine because its functioning is so integrated with other components of that engine such as the compressor, combustor, etc. This required a close participation of both the control manufacturer and the engine manufacturer during development and production phases.

A good many questions were asked following formal presentation of the talks. Space will permit presentation of only one bearing on starting and troubles caused by incorrect fuel programming. The question was asked:

"Please tell how the turbine is started and what is a 'hot start' and 'hung start?' "

"On the particular helicopter application under discussion, electrical starting is used. In a battery system, a starter and generator or a combination starter-generator unit is required. Since in this case a generator is mounted on the helicopter transmission, we use a simple starter. Engagement is in the accessory gear box and drive is back through this unit to the compressor rotor and its turbine. There is an over-running clutch arrangement such that when the engine is up to self-sustaining power and speed, disengagement from the starter is automatic.

"In this T53L-1 engine, ground idle speed is 40% of maximum speed. The starter, without outside help or aid from combustion, will crank the engine to approximately 18% to 22% speed. In normal cranking procedure, fuel is bled from the fuel pump to a primer system and into the combustion chamber. The engine is self-sustaining at approximately 25% to 30% speed. Ignition starts prior to reaching the 18% cranking speed and with the help of preliminary combustion, the engine accelerates smoothly through the cranking speed up to the 40% ground idle speed.

"The 'hot start' and 'hung start' terminology has been used for quite some time. I would define the 'hot start' as one in which the tailpipe temperature thermocouple senses an over-temperature condition during starting. This is a transient condition generally due to excessive fuel introduced in the starting process.

"The 'hung start' condition may occur in the course of the starting cycle and at about 25% speed. You have more fuel than required to accelerate the engine and you overtemperature it. If the engine goes for enough over temperature, it stops accelerating and just cooks. Then you have burned turbine wheels, burned nozzles and other disastrous things that we don't like. These conditions can generally be avoided by use of proper fuel controls."

Plot of tensile-impact properties indicates that the recommended hot working range of Carpenter's V-57 alloy in wrought form lies between 1700 and 2000°F.

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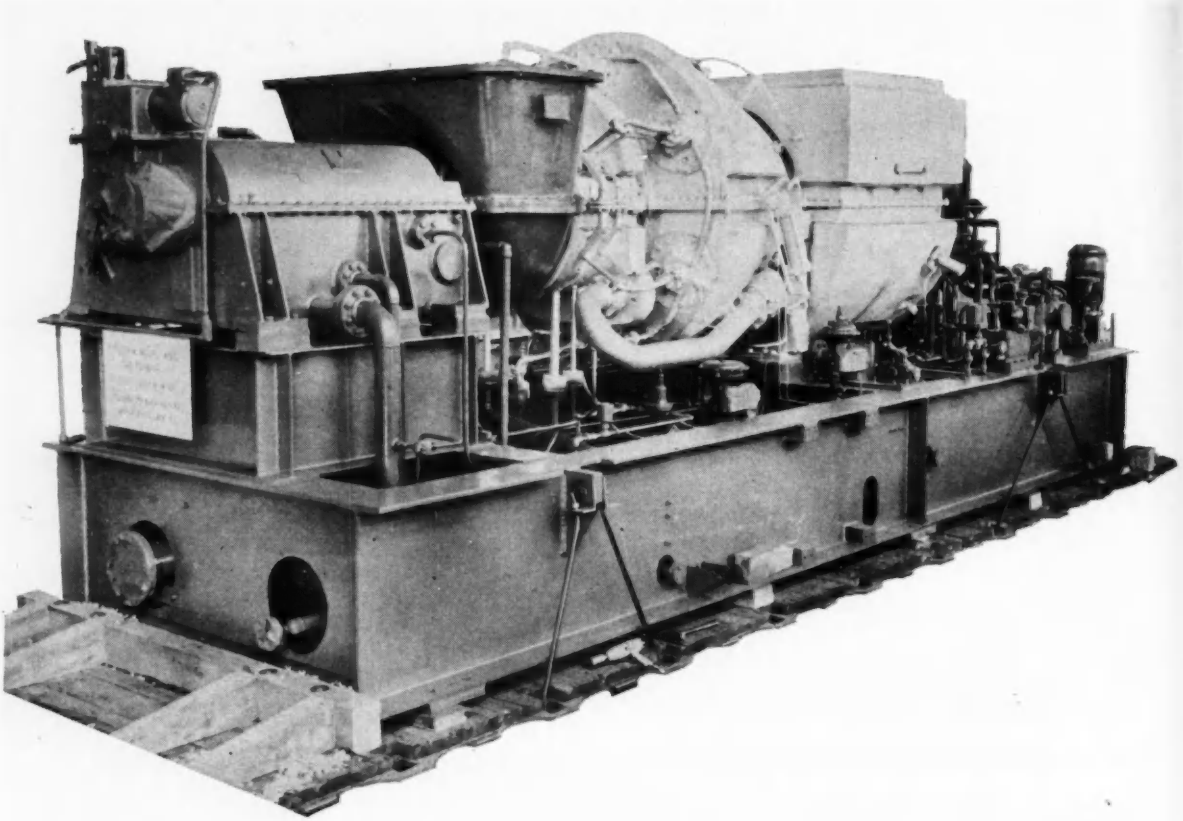


Gas Turbine in Combined Cycle...

Boosts overall plant efficiency — Offers other solid advantages

A WESTINGHOUSE ELECTRIC CORPORATION 5320-kw gas turbine peaking plant is being added to the city of Austin, Minnesota, power plant. Capacity of the present steam plant is about 20,000 kw. Future plans call for addition of a 22,000-kw steam plant by 1965, bringing the total ultimate capacity to 47,185 kw. The turbine, ready for shipment, is shown.

After considerable study by J. V. Edeskuty & Associates in conjunction with the Austin Utilities, selection of a gas turbine to meet present peaking requirements and future addition of a 22,000-kw steam plant offered the most economical approach to future power requirements.

Advantages of this type of combined cycle over a conventional steam plant of 27,320 kw were:

1. Improvement in efficiency.
2. Reduction in steam flow.
3. Reduction in circulating water and water treatment system.
4. Elimination of forced draft fans.
5. Elimination of air heaters for the boiler.
6. Reduced building size.
7. Reduction in auxiliary power requirements.

All of these improvements do not come without some additions that must be considered. To recuperate the heat used by the air heater, an additional economizer or stack gas cooler must be added. However, gains in equipment sizing more than compensate for cost of the added economizer with continuous gain in efficiency remaining as the big saving in favor of this type plant.

Careful review was made of prior operating experience with this exact same turbine type. At the time the machine was purchased, there were 44 gas turbines of this same frame in the field with 681,750 hours of operation. First of the machines was placed in service in 1952 at Ft. Stockton, Texas and had accumulated in excess of 50,000 hours in base load operation with an average load that was 10% above its nameplate rating.

Turbine Details

The Austin, Minn. gas turbine consists of an axial flow compressor, six combustors and a reaction turbine as shown in the sectional view. The 16-stage axial flow compressor swallows 3½ ton of air per minute and com-

presses it to 70 psig. Approximately 11,000 kw are used by the compressor in compressing this air.

At a temperature in excess of 500°F, air enters the combustion chambers where either gas or oil is burned to raise the temperature to 1350°F. At this point it enters a 5-stage reaction turbine where it is expanded to atmospheric pressure and 740°F. The turbine extracts approximately 16,500 kw from the hot gases which is sufficient to drive the 11,000-kw axial flow compressor and have 5500 kw for the generator.

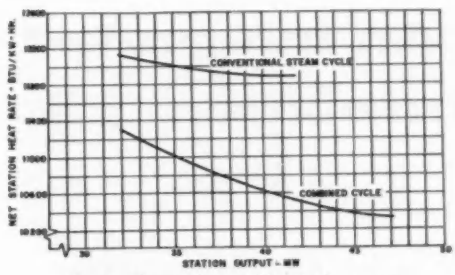
Salient features in this gas turbine design are:

1. Only two bearings support the rotating element. This minimizes alignment problems as well as eliminating a potential fire hazard as when a bearing is located between compressor and turbine.
2. Curvic couplings are used in the turbine rotor.
3. Tangential exhaust bearing support struts. These connect the outer cylinder to the bearing housing at a tangent so that unequal heating of the struts with respect to the cylinder merely causes the bearing housing to rotate and stay coaxial to the cylinder.
4. Compressor rotating blades locked in broached disc slots such that individual blade change-out can be accomplished.
5. Compressor stationary vanes welded in removable segments for rigid support and to facilitate inspection.
6. Turbine rotating blades in broached serrated slots—again for individual blade change-out.
7. Turbine stationary blades also welded in segments for ease of inspection.
8. Combustor baskets completely enclosed and having enclosed interconnection. Each combustor basket can be removed for inspection in a matter of minutes.

Performance and Economies

As mentioned earlier, the 5500-kw gas turbine is being initially installed for peaking service and ultimately is to be combined with a 22-mw steam turbine, plus added feed water heaters for other machines in the station. Turbine location in the boiler room facilitated minimum ducting to the boilers and feed water heaters.

Overall plant thermal efficiency, including the gas turbine, is calculated at 33.08%. Without the gas turbine, efficiency is estimated to be 28.71%. Ultimate station capacity will be 47,185 kw with the gas turbine



Comparison of specific fuel curves

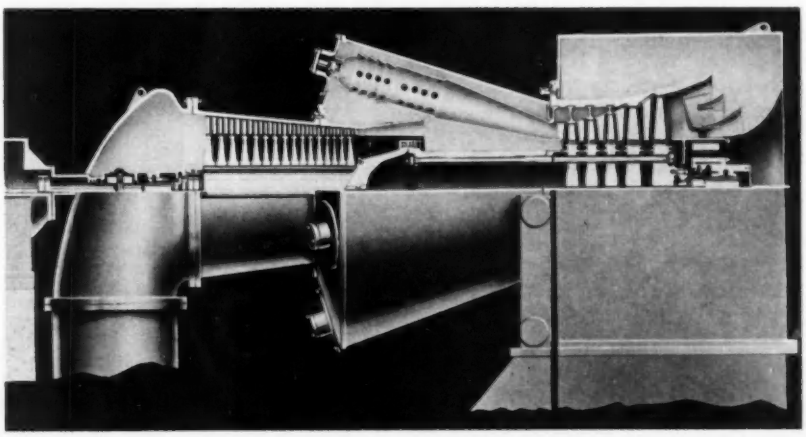
exhaust heat fully utilized. When considered with the conventional steam plant addition, this represented a reduction in fuel consumption of approximately 15.22% or 4.37 percentage points.

This gain represents the magnitude of what may be accomplished with addition of gas turbines to existing plus future steam plants. A more modest gain would be expected on a new plant with all new steam equipment. In any event, the gain is appreciable.

Part-load performance of this plant combination is indicated in the chart. No credit has been taken for cool weather operation where lower ambient temperatures increase capability of the gas turbine up to 7000 kw. Also, it supplies more hot combustion air for the boiler which, in turn, can meet all over-load capacity.

Operation of the gas turbine has confirmed all expectations for the peaking plant concept and has exceeded its guaranteed fuel consumption rate. A critical analysis of the future heat balance of the entire station has been made and, at this point, it appears that the expected gains will be met if not exceeded.

This combination of steam turbine-gas turbine plant essentially improves the air side of the steam cycle, resulting in the economies indicated by the efficiency improvements. All locations, where natural gas or distillate oil is available for burning in the gas turbine, can obtain some degree of improvement. Since only 20% of the fuel consumed is in the gas turbine, many arrangements that are now considered for only coal-burning may reap similar benefits by applying the gas turbine-steam turbine combination where this percentage of gas or distillate oil can be made available for the gas turbine.



Partially-sectioned view showing major components and flow path of 5000-kw gas turbine.

An Integrated Turbo/Generator Unit

by Dr. R. A. M. Toesca, Vice President
Energy Transformation Corp.

TO BRING DOWN weight and size of the prime mover, gas turbines in the 10 to 100-hp power range have been designed to operate at very high speeds—sometimes above 60,000 rpm. Result is that it is possible to design a 100-hp basic gas turbine weighing 35 pounds or less. But to drive the accessories (fuel and oil pumps, controls), the electrical load, and to connect the starting power (whether electric or man-produced), relatively complicated and heavy gear boxes have been used. A lightweight 100-hp gas turbine which weighs basically 35 pounds gains to 80 or more pounds without generator. Cost of the engine grows sometimes even more than weight and, due to the added complexity, reliability sometimes suffers.

New Design Philosophy

To provide maximum reliability and simplicity with minimum cost, design of a gas turbine generator set has been conceived in a new way. Instead of designing two separate units and coupling them, a single electrical power generating unit was designed without need for compromise. Design goal in the turbine itself was not shaft power but electric power. The compressor wheel, the turbine wheel and the generator wheel are all mounted on a single shaft turning on only two bearings.

No gears, accessories drive or control drives are connected to the shaft. The whole design has been directed towards keeping the rotor simple. It allows non-rotating parts to be very simple—symmetrical with respect to the axis—and inexpensive. The resulting integrated gas turbine generator unit, the I.G.T.G.U., is the smallest in its power range (100 hp maximum). This is not done at the expense of high stresses, high speeds, close clearances and very low tolerances; it is possible because of its conception.

Size and Performance

The 20-kw unit weighs 85 lb, measures 16-in. long and its speed is only 33,000 rpm. The 40-kw units weigh 90 lb and turns at 39,000 rpm. Except for shaft fits, tolerances are liberal. For instance, turbine nozzle areas are held only within a sixteenth inch. Little penalty in fuel consumption has resulted from this approach. Fuel consumption with 1460°F turbine inlet is 1.35 lb per hp-hr, 1.2 lb per hp-hr with 1630°F (100 hp). Also, it is felt that these can be improved considerably. The gas turbine can idle at a speed as low as 5000 rpm.

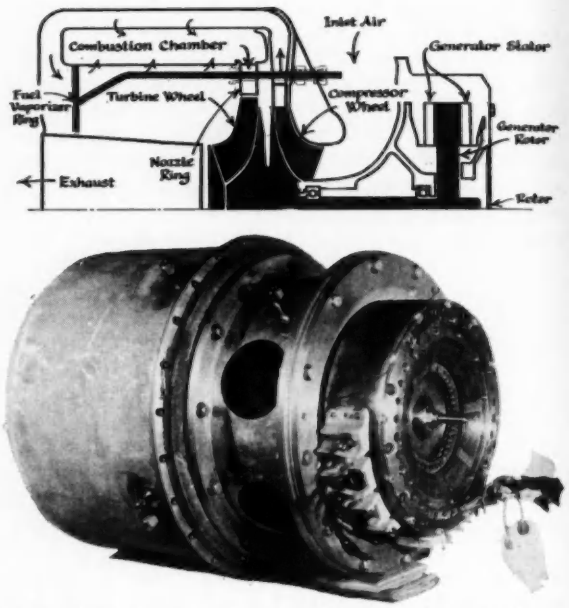


Fig. 1 Complete unit with schematic above showing relationship of components and indicating the gas flow path.

Costs

Selling price of the gas turbine set without the electromagnetics is $1500 in quantities of 100 units and $1000 in quantities of 1000. These prices are quoted for 100-hp maximum output.

These units have practically universal application as the same complete gas turbine generator assembly can be used to produce d-c, a-c 60 cps, a-c 400 cps, a-c 2000 cps or any other frequency desired or any combination of these. An adjunct to the unit is an electronic "black box", the frequency changer. Use of a high generator output frequency, 8000 at 32,000 rpm, allows use of a very small frequency changer. This capability to provide several a-c frequencies and for d-c should broaden application and considerably increase production quantities, thus decreasing cost even further.

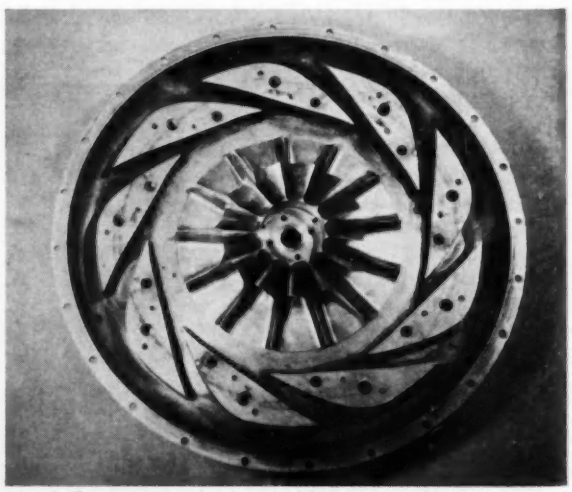


Fig. 2 Compressor wheel and diffuser assembly.

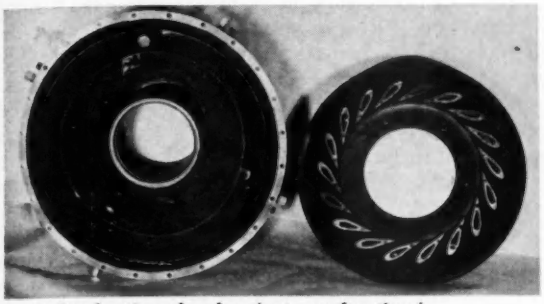


Fig. 3 Combustion chamber (note perforations) and turbine nozzle ring assembly.

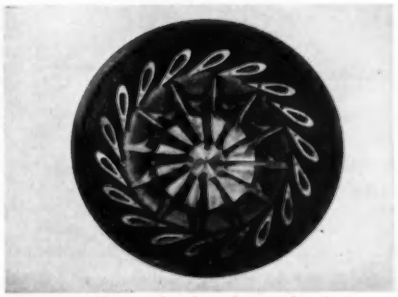


Fig. 4 Turbine wheel and nozzle ring in their working relationship.

Details of the 20-40-kw Unit

Aerodynamic components of the I.G.T.G.U. are conventional, (Fig. 1). Air enters a symmetrical compressor inlet, is compressed through a centrifugal compressor (Fig. 2). Combustion takes place in a low pressure-drop annular can containing the fuel vaporizers and the starting fuel atomizer (Fig. 3). Exhaust gases expand through the turbine nozzles and drive the turbine wheel (Fig. 4)

Compressor and turbine wheels are mounted back-to-back on the shaft, outboard of a ball bearing. At the other end of the shaft the generator rotor is mounted outboard of a roller bearing (Fig. 5). Because of the moderate speeds, both compressor and turbine wheels can be cast, making possible the lowest production cost.

The generator is an axial airgap version of homopolar inductor alternator with no windings on the rotor. Electric power is generated by cyclic variations in the magnetic coupling between the field and armature winding. The field winding is at the periphery of the stator and the power windings in slots in the stator faces. The generator stator and rotor are shown in Fig. 6 and the assembling of the generator stator can be seen on the right of Figure 1. In contrast to most designs there is no change in the flux direction in the generator, just variations from maximum to minimum, etc.

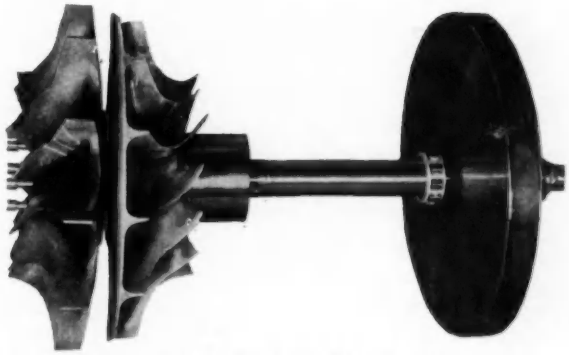


Fig. 5 Rotor assembly. From left, turbine wheel, compressor wheel and generator rotor.

Fuel System

Speed control is extremely simple and effective. The fuel line in addition to carrying the fuel to the combustion chamber, carries back the "speed signal" and the system is "fail safe". The fuel pump is driven by an electric motor connected to the generator output. It supplies fuel to the vaporizer through an adjustable relief valve which is the only control, Fig. 7.

Fuel pressure at the relief valve discharge is set to be practically equal to compressor pressure. At a constant compressor pressure, rotor speed varies only $\pm 2.5\%$ with load changes. However, if the engine accelerates, combustion chamber pressure increases and thus becomes higher than fuel pressure. Therefore, no fuel reaches the combustors.

A failure of the relief valve is very unlikely as it is designed with large clearances around the piston and a leakage area is provided to keep its maximum fuel outlet pressure at a level below combustor pressure in an overspeeding turbine condition. Operating speed can be changed manually by changing spring tension on the relief valve.

To protect agaist man-induced overspeed, a second relief valve can be installed. This has a fixed setting to keep fuel at a pressure below the fuel pressure at maximum speed. Speed control is needed only to provide enough power output as output frequency can be controlled electronically, as precisely as can be desired. This is not always the case with conventional gas turbine speed controls.

Lubrication

The oil pump is driven by the same motor as the fuel pump. There are only two lubrication points, the

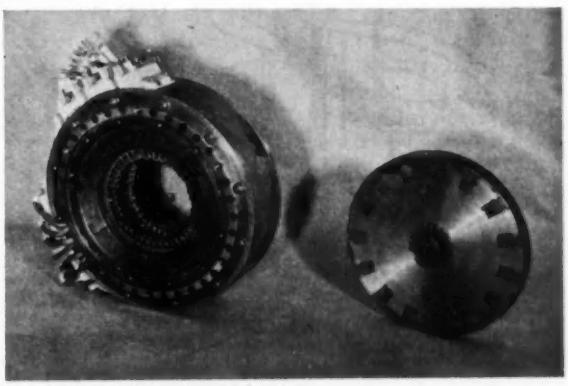


Fig. 6 Generator stator and rotor.

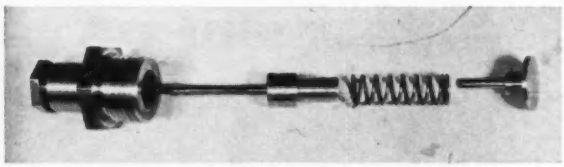


Fig. 7 Exploded view showing components of the simple fuel system relief valve, the only control used.

ball and the roller bearings. There is no oil sump; oil returns to a tank separated from the engine.

Starting

The unit is started pneumatically with low-pressure air produced either by a fan driven by a starting motor or by a crank with step-up gears. Unlike other pneumatic starting systems, no special nozzle is needed. Air is sent directly to the compressor inlet. With an air pressure of 9 in. of water (corresponding to 0.15 hp), the basic engine accelerates to 18,000 rpm in eight seconds. As is the case with the oil and fuel pumps, the starting system can be remotely located. It can be disconnected, if desired, after starting.

Service Accessibility

The unit can be disassembled from either end. The combustion chamber can be removed in a few minutes. So can the generator rotor. The complete unit can be completely disassembled in one hour including wheels and bearings.

Future Outlook and Markets

The pictured I.G.T.G.U. is a first step in production of real lightweight portable power. The drawing, Fig. 8, shows a unit capable of producing 30 kw at from 0 to 40,000 feet and which will weigh less than 50 lb. It utilizes a single-stage supersonic compressor and, like the present unit, it is designed to provide maximum serviceability. It is not designed to replace piston engines or other existing prime movers but to supplement them.

It will make possible technical realizations not dreamed of before such as: powerful radio broadcasting stations (all in plug-in components) that can be entirely carried by men; observation stations comprised of (1) a miniature helicopter carrying a television camera and (2) ground control; a 30-kw searchlight; new types of low-silhouette vehicles with power in each wheel or track.

Once designers are aware that such a lightweight power source is available, that it is flexible enough to give them the kind of currents they want at a moderate price, new horizons will open for the gas turbine. Meanwhile the present unit should find its place readily in applications of intermittent or emergency service, as well as in cases where portability is desired. Examples are starters for large jet engines; winterization of army vehicles; auxiliary power for aircraft and helicopters, for hydrofoils and boats; power source for large civil defense shelters; emergency units for hospitals, schools, etc.

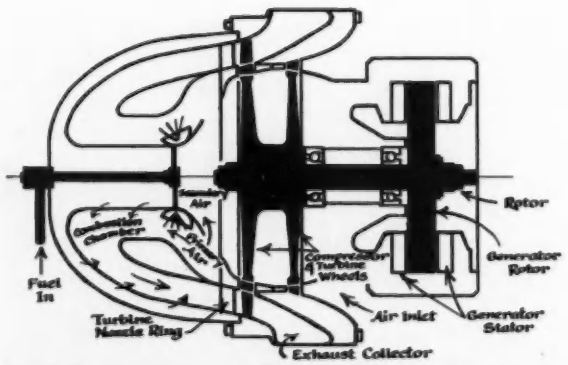


Fig. 8 Simplified drawing showing components, their relationship and gas flow path of a 30-kw unit.

Background

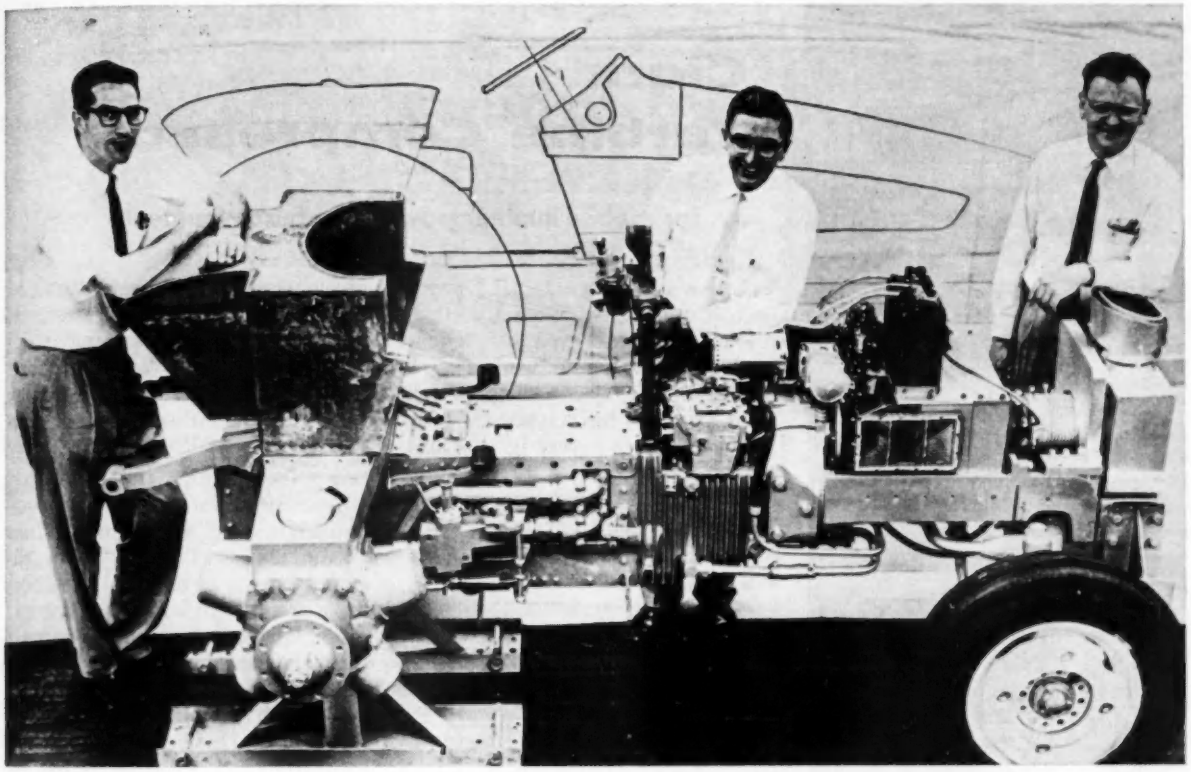
The Integrated Gas Turbine Generator Unit was developed by Energy Transformation Corporation in collaboration with David Budworth, Ltd. of Harwich, England and the General Electric Company. The electromagnetics were not designed specially for this unit. Generator parts utilized in the first unit came from a prototype developed by the D.C. Motor and Generator Department of the General Electric Company (Erie, Pa.) in a joint program with the U. S. Navy (Bureau of Weapons). They were modified to provide better cooling of the windings.

The original generator was conceived to produce a constant frequency from the variable speed of the auxiliary pad of a jet engine. Its variable frequency output is transformed into d-c or into any precisely-controlled frequency desired, through a static frequency changer. This is basically a set of controlled rectifiers, controlled by an oscillator. The frequency changer is built by the Specialty Control Department of the General Electric Company at Waynesboro, Virginia.

Since the generator was designed to give the full 20-kw at 16,000 rpm, the magnetics are quite oversized at 32,000 rpm. A specific design for that speed would result in a much smaller, lighter unit. The present generator under overload conditions supplied a short-time output of 51 kw.

Energy Transformation Corporation is pleased to express its gratitude to the U.S. Navy (Bureau of Weapons) and the General Electric Company who made possible realization of the Integrated Gas Turbine Generator Unit.

Energy Transformation Corporation is an 80%-owned subsidiary of Aero Industries, Inc. of Boyertown, Pennsylvania, which also includes Jacobs Aircraft Engine Company of Pottstown, Pennsylvania, Atlantic Aviation Corporation and Feedback Systems Division of Boyertown, Pennsylvania and Franklin Engine Division (formerly Aircooled Motors) of Syracuse, New York.—Ed.



IH Engineering Research personnel, L to R, John R. Cromack, test engineer, Carl H. Meile, chief engineer, and Ralph Wallace, research engineer, with experimental tractor. At rear, skin styling is sketched full scale. Turbine is at right with side intake and front exhaust. Pump is in center; radial hydraulic motors at wheels, left, with fuel tank mounted on cross member.

Turbo/hydrostatic drive . . . tractor power of the future?

Under the sleek-lined fiberglass skin of the newest research tractor, International Harvester Company has paired a Solar gas turbine with a hydrostatic transmission. The company believes this may be the first time the combination has ever been tried in a farm and utility tractor. It was unveiled at the 10th Annual Tractor Day, University of Nebraska, according to an announcement by A. E. W. Johnson, Harvester's vice president of Engineering, and C. H. Meile, chief engineer, Engineering Research.

Called the HT-340, this striking concept of things to come in the tractor line has no gear shift lever, no throttle, no brake or clutch pedals. It uses neither cooling water nor anti-freeze and it has no transmission gears.

Its oil consumption is almost nil and it will operate on virtually any kind of liquid fuel. Its forward and reverse speeds are infinitely variable; it starts readily at low temperatures and is notably free of vibration. Its acceleration and torque characteristics are excellent.

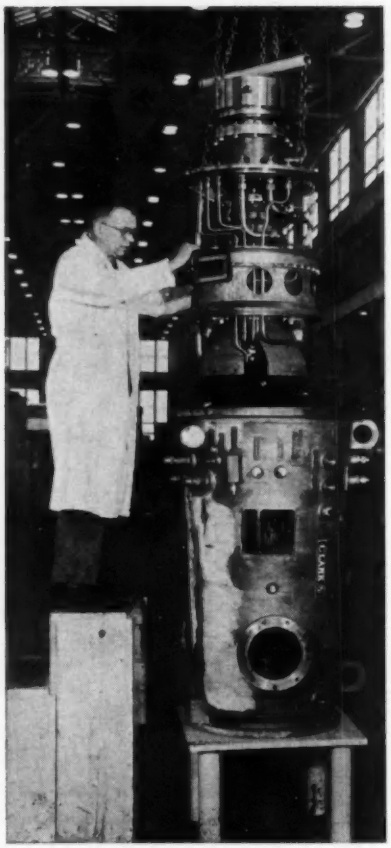
The gas turbine, an 80-hp, single-shaft Titan T62T, is a product of the Solar Aircraft Company, Harvester's San Diego subsidiary. It is 21-in. long, less than 13-in. in diameter and weighs only 90 lb with reduction gearing. The engine is one of the smallest gas turbines ever built for this purpose.

It's this simplicity of design that creates such gas turbine advantages as (1) freedom from vibration—a smoothly spinning turbine wheel and shaft replaces the reciprocating masses which cause vibration in piston engines; (2) freedom from conventional maintenance problems; and (3) oil consumption that is virtually nil —only a few bearings need lubrication.

In a ground vehicle, a constant-speed turbine is particularly well-matched with a hydrostatic transmission to provide speed variation. For purposes of research, the HT-340's engine and transmission complement each other perfectly.

The hydrostatic system devised by IH researchers has three major parts (see schematic)—a variable-displacement pump that furnishes oil pressure energy to a pair of radial hydraulic motors, one in each driving wheel. This system eliminates need of gearing since torque

(*Continued on next page*)



Clark Turbine Compressor

. . . for mobile nuclear power plant, goes on test

CLARK Bros. Co., Div. of Dresser Industries, Inc., has announced that it's new turbine-compressor, scheduled for use in the world's first mobile nuclear gas turbine power plant (330 kw) has reached the testing stage. Over a year in development, the turbine will be incorporated into a compact power conversion skid. This operates in conjunction with the Army ML-1 portable reactor skid as a closed-cycle, gas-cooled reactor turbo-generating system.

Clark's turbine may also be incorporated with a fossil-fueled, closed-cycle heater to develop data on operational characteristics of closed-cycle gas turbine systems. Aerojet General Corporation is developing the ML-1 for the Department of Defense under contract with the US Army Corps of Engineers and the US Atomic Energy Commission.

Closed-cycle gas turbine designed for use in 330-kw mobile nuclear power plant during final assembly.

Concept of a mobile nuclear power plant involves use of nitrogen in a pressurized closed-cycle system. Nitrogen is introduced to the compressor at about eight atmospheres, compressed to 20 atmospheres, passed through a recuperator to pick up heat from turbine exhaust and enters the reactor that raises its temperature to 1200°F. It then expands in the turbine, providing energy to drive the compressors and generator.

Turbo/Hydrostatic Drive . . .

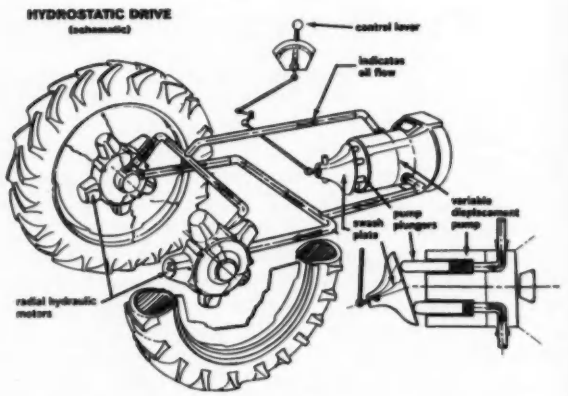
(*Continued from previous page*)

produced at the wheels is primarily a function of hydraulic pressure produced. Vehicle speeds are controlled in infinitely-variable steps by change of plunger stroke (displacement) in the pump.

A single lever effects control. Tilting the swashplate controls vehicle speed; the greater the pistons' stroke the higher the speed. In neutral there is a hydraulic braking action and tilting the swashplate beyond the neutral position has the effect of reversing the fluid flow in the system and hence reversing the vehicle.

"We built this tractor because we are aware of the problems it poses." Mr. Meile says. "We want to get experience for a quantitative evaluation of this type of power system. Despite recent progress, fuel economy remains a big question in the minds of all who are interested in using turbines to propel ground vehicles. We are certainly making no claims for the HT-340's fuel economy.

"At this point in our research program, we haven't even tried to improve it. Heat exchangers, or regenerators, to recover heat from exhaust for preheating intake air, would seem to be the answer. We are already working with regenerative-cycle engines. That will be our next step. It will also solve the problem of heat at the exhaust stack, which, with a regenerator, will actually be less than that in a piston engine.



Hydrostatic drive components and their relationship.

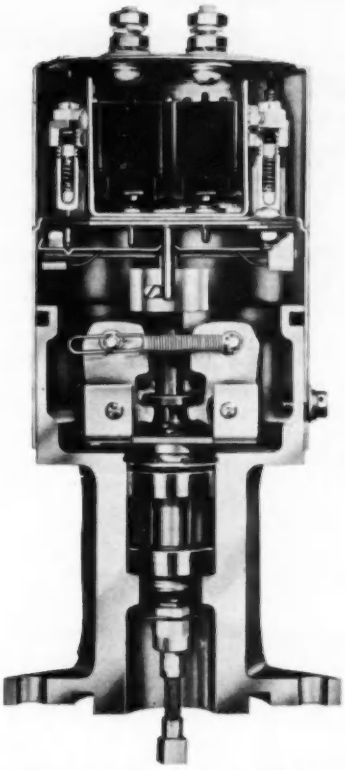
"Noise is another gas turbine problem. But," according to Meile, "it's no louder, at full throttle, in the HT-340 than in a conventional tractor engine. These engines can be effectively silenced."

Much research must yet be completed with heat-resistant materials and precise production methods before the gas turbine can become a competitive, commercial power source for a farm tractor. But interest is running high, and beyond a doubt, the problems will be solved.

PRODUCT REPORT:

Control by Speed-Sensing

How certain phases of industrial gas turbine control can be handled automatically as a function of rpm by versatile, multi-element speed switches.



GA-2 2-element speed-sensitive switch. Spring and switch, top left, is low-speed switch; high-speed switch is at right. GA style mounting fits AND20005 tachometer pad, is most popular.

"IF I HAD KNOWN about these items a few months ago, I would have used them in some gas turbine controls that we worked out . . . and saved ourselves a lot of effort." This is a comment made by a controls application engineer. It is typical of a general problem—finding a suitable product in production, possibly for a different field, that can be used directly or adapted. This is particularly true in a field as new as that of gas turbines . . . and a reason for publishing product reports.

The items to which this engineer referred were speed switches, products of Syncro-Start Products, Inc. As a matter of fact, they have been used since 1951 on industrial gas turbines. They have proven both reliable and accurate for this type of application. There are several versions, their versatility meriting a review.

Sensing Element

Basically, these are mechanical speed-sensing units. A flyweight mechanism, driven from the unit to be monitored, senses speed through the centrifugal force acting on the flyweights. Toes of the flyweights convert outward movement to linear motion for switch actuation.

A variety of drives and mountings make the unit applicable to a number of specific uses. Internal arrangement and the number of switches used makes the unit suitable for functioning at one preset speed or at several points in the speed range.

Switching Arrangements

With a single switching element, the flyweight mechanism actuates a single-pole, double-throw, snap-acting set of contacts rated 10 amp, 115 v. a-c. This will occur at the preset speed. A typical application would be to use the unit as a overspeed cutoff.

Hookup of these contacts is usually such that they energize (or de-energize) a solenoid or other electrical device that performs the actual function required. Various types of solenoids and contactors are available.

A 2-element unit (illustrated) has two switch contacts that operate at different speeds. When applied to either gas turbines or other engine types, the low-speed contact is commonly used to disconnect the starting circuit after the engine begins to operate under its own power. The high-speed contact is used to provide overspeed in case of speed control governor failure.

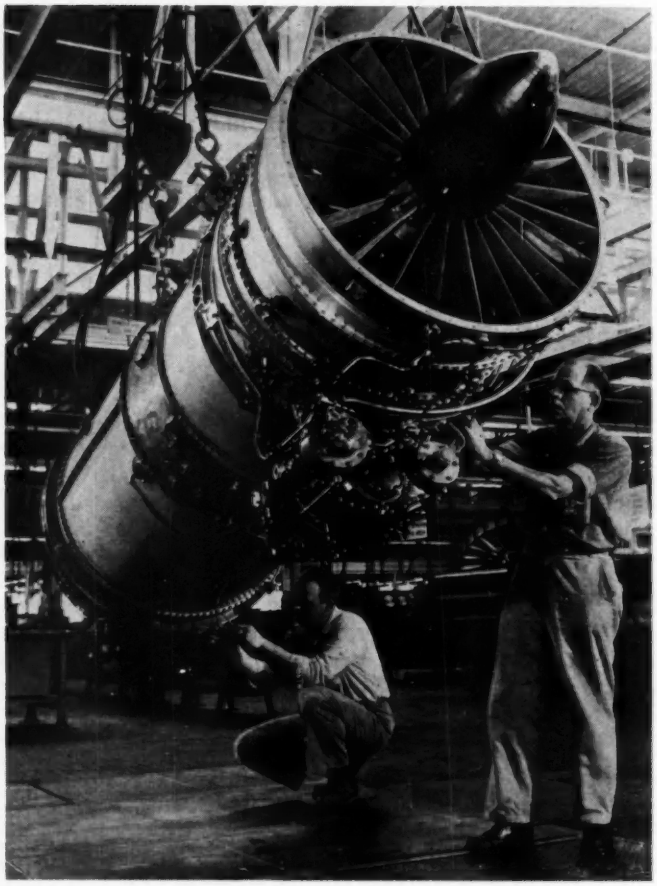
Three-element speed-sensitive switches are generally used in the more sophisticated control systems. The low-speed contact, for example, could be used to energize the ignitor circuit after the starter had gotten the turbine up to recommended speed. The intermediate-speed contact might be used to disconnect the ignitor and starter circuits after the turbine began to run under its own power. The third and high-speed element is then used for overspeed protection.

Recently, the number of available switch contacts has been increased to control as many as four, five and six circuits. Each operating point in the 3-switch governor operates either one or two adjustable switching elements. For four circuits, a dual assembly would be actuated by the first operating point and two single switch assemblies would each be operated by one of the remaining operating points.

For control of five circuits, two dual and one single switch assembly would be used. Use of three dual switch assemblies affords a maximum of six adjustable switching elements for control of six circuits. Each switch has separate normally-open and normally-closed contacts.

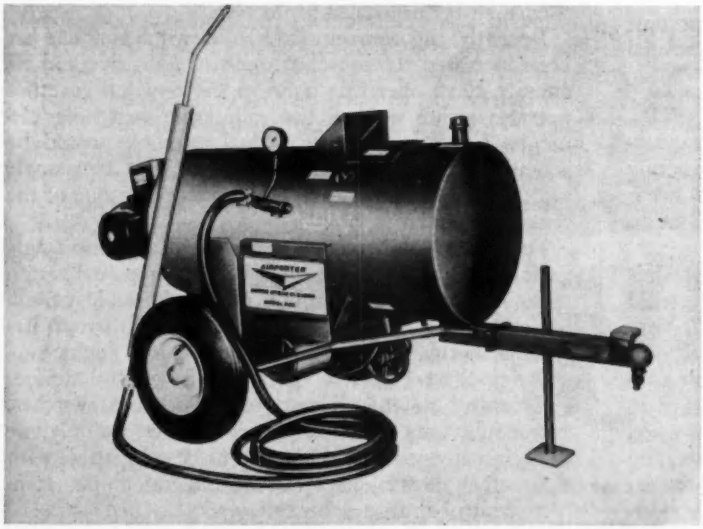
Syncro-Start Products specializes in control devices and control systems. These particular speed switches, successfully used on industrial gas turbines, are only one of their many products. Designed to be compatible with their other devices, they can be integrated into complete control and/or alarm systems.

GT PRODUCT NEWS



First Development JT8D Turbofan Engine
Preparations are underway here at the Pratt & Whitney Aircraft plant in East Hartford, Conn. to place the engine in a test stand. The JT8D will power Boeing's 727 short-to-medium range, 3-engined jetliner now on order by several airlines. New turbofan weighs 2904 lb, develops 14,000-lb thrust. Testing in flying testbed is scheduled soon.
925

Cyrogenic Metal Seal
From Rocketdyne Division of North American Aviation, Inc. comes the "Naflex" seal, reported proven in engineering tests and in liquid rocket engine operational flights. Seals in aluminum with Teflon-covered sealing points come in sizes for one to 20-in. Also, special high-temperature, extreme pressure designs and engineering are available.
926



Aircraft Engine Steam Cleaner
The Airporter, Model 220 Steam Cleaner has been designed and engineered especially for the aircraft industry by people from the industry. These units are currently in use by aircraft companies, airport operators and repair stations throughout the country. Built by Electronics, Inc., these cleaners can not only be used for engine cleaning but for many other phases of shop work.
927

Hydrodyne Seals

Hydrodyne Corporation's special bellows type rotary face seal is used where minimum envelope length is required. The unit is used in Oronite 8200 systems. Constructed of Stainless Steel, the assembly is subjected to 2000-psi surge pressures and a normal operating pressure of 500-psi. Actual burst pressure is in excess of 5000-psi. Temperature range is −65 to +520° F.

928

New Chatillon Absorption Dynamometer

A new absorption dynamometer which has a specially-designed hysteresis brake in order to reduce starting torque and to improve high-speed performance has been developed by John Chatillon & Sons, New York. Another important feature of the new instrument is an automatic transfer of torque ranges through a progressive spring loading system. Known as the 1200 series, the new unit applies a restraining torque to prime rotary movers, such as electrical, hydraulic or air motors, turbines and rotary spring activators, and measures the magnitude of the applied torque.

The rotor under test drives the brake's rotor which the magnetically coupled stator tries to follow, but is restricted by the reaction of the springs. The amount of this reactive force is transmitted to the unit's dial, where it is read in terms of inch-ounces, or inch-pounds. A photo-electric tachometer which is included as standard equipment eliminates mechanical contact between the shaft and transducer.

929

Lube Oil Clarifier-Coalescer

Mr. Charles S. Schmulker, president of Marine Moisture Control Co., Inc., announced the receipt of a contract to supply a lube oil clarifier-coalescer for the main gas turbine reduction gear case. The unit will operate continuously.

The hydrofoil ship is being built for the U.S. Maritime Administration by Dynamic Developments, a subsidiary of Grumman Aircraft Engineering Corp. It is scheduled for launching sometime this fall.

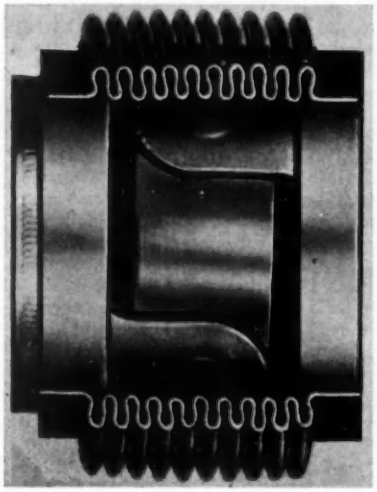
930

Lycoming's New Turboprop Engine

Development and successful first test run of a new turboprop engine by Avco Corporation's Lycoming Division, Stratford, Connecticut, was announced today by James R. Kerr, president.

Designated as Lycoming model LTC4G-3, the new engine is rated at 2535-eshp. It is essentially a greatly improved version of the earlier 1600-shp T55-L-1 engine that was developed by Lycoming under Air Force contract. The 2535-eshp rating of LTC4G-3 of 795-lbs weight is the same as the uprated 2590-eshp T55-L-5, with turboprop gear losses deducted.

931



Flexonic Flexible Joints

Quality-controlled flexible joints are available for absorption of thermal growth where space and weight savings are critical. Free-flexing joints capable of axial and/or radial motion and self-restrained joints suited for angular deflection are available from the manufacturer. Completely leaktight, the units have been proven through use on aircraft gas turbine engines and can easily be adapted to gas turbine applications wherever motion absorption is necessary. Flexonic offers a completely illustrated catalog including specific engineering data on flexible joints, pin, link and gimbal. An application check list covering critical areas of design is also included.

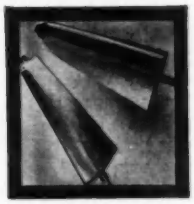
932

STALKER salutes

the new

TWA Convair SUPERJET

Stalker is proud to have had a part in developing and producing the light weight, precision-fabricated inlet guide vanes, a part of each of the four General Electric CJ 805-3 engines used for powering the TWA Convair Super Jet airliner.



Stalker product developments for the aviation industry include many precision-fabricated jet engine parts — rotors, stator vanes, nozzles, air-cooled turbine buckets — all incorporating Stalker's proven Orthobraze methods. Stalker is equipped to handle both aerodynamic and structural testing of compressor components. Stalker quality control and inspection is USAF approved.

THE STALKER CORPORATION

Phone: Bay City — TWinbrook 3-7562

905 Woodside Avenue
Essexville, Michigan

For more information write in No. 910

GT PATENTS

By J. W. Sawyer

CONTROL FOR CARTRIDGE STARTER (2,984,976) 7 CLAIMS Emil A. Volk, Jr., Hasbrouck Heights, N. J., assignor to The Bendix Corp. An improved solid propellant starter having combination speed sensitive and pressure sensitive means for diverting gases from the starter turbine which does not require electrical power.

BLADED ROTOR CONSTRUCTION FOR AXIAL-FLOW FLUID MACHINE (2,985,426) 21 CLAIMS Philip E. Hunter, Chellaston, G. G. Davison, Alvaston, Wilfred H. Wilkinson, Turnditch, and Douglas H. Williamson, South Kirby, Pontefract, England, assignors to Rolls-Royce Limited, Derby, England. A rotor construction in which at least some of the axially-extending passages between the circumferentially-narrow stems of the blades are sealed.

STATOR UNITS (2,984,454) 7 CLAIMS Bruno M. Fiori, East Hartford, Conn., assignor to United Aircraft Corporation, East Hartford, Conn. Stator construction in which the individual vanes may be locked in their particular position by a mechanism which, if it should break loose, would not enter the powerplant gas stream and further, in which the stator unit fabrication is such that gas loading would tend to maintain the component parts of the stator assembled, should the lock mechanism disengage.

FUEL CONTROL SYSTEM (2,983,100) 10 CLAIMS Howard H. Dietrich, Rochester, and Frank B. Page, Pattersonville, N. Y., assignors to General Motors Corp., Detroit, Mich. Fuel system including means for maintaining a pressure drop across a regulator and a governor proportional to compressor discharge total pressure irrespective of variations in the inlet fuel pressure; and the further provision of a fuel system including means for varying the pressure drop across a governor controlled orifice to produce a fuel flow directly proportional to the difference between regulator inlet fuel pressure and governor outlet fuel pressure during variation in compressor discharge total pressure at the control position, and where the fuel pressure drop between the regulator inlet and the governor outlet is directly proportional to compressor discharge total pressure.

METHOD FOR FABRICATING TURBINE ASSEMBLY (2,983,922) 7 CLAIMS David J. Bloomberg, Newton, Mass., assignor to David J. Bloomberg, Inc., Newton, Mass. Provides the following improvements in methods for fabricating turbine wheels with buckets attached: (1) preheating of turbine buckets for attachment to a molten wheel without oxidation or impairment of bucket strength, (2) precasting of buckets or nozzle diaphragms and maintaining these in proper positions for additional fabrication operations, (3) turbine wheel assembly which has sufficient strength, light weight and good vibration resistance, (4) fabrication of complete wheels by techniques suited to a high degree of automation.

ROTARY DISC REGENERATOR (2,981,521) 8 CLAIMS Ted C. Evans and Charles A. Lyle, Wellsville, N. Y., assignors to The Air Preheater Corporation, New York, N. Y. A rotary regenerative heat exchanger whose sealing surfaces are not subject to the usual excesses of thermal distortion and permit relative distortion of the rotating parts without impairing the sealing relationship between them.

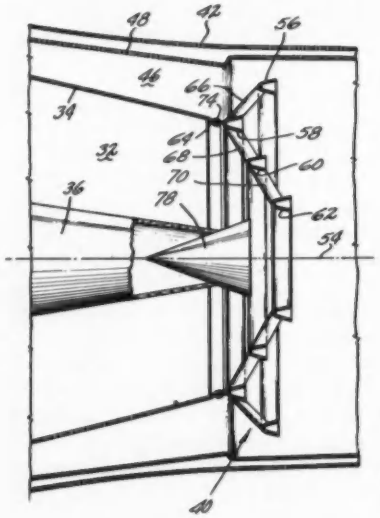
FAIL-SAFE AFTERBURNER FUEL CONTROL (2,980,176) 8 CLAIMS Bruce N. Torell, Wethersfield, Conn., assignor to United Aircraft Corporation, East Hartford, Conn. A fail-safe device for an afterburner fuel system which assures afterburning operation of a gas turbine power plant, and which permits complete operation of the power plant throughout the non-afterburning range.

STARTING CONTROL FOR GAS TURBINE ENGINES (2,980,173) 9 CLAIMS Russell C. Perkey, South Bend, Ind., assignor to The Bendix Corp. In addition to other features provides an improved engine starting fuel control which will temporarily make the normal operation fuel metering means inoperative until after the engine has been started or until the engine has assumed some predetermined operative condition such as the idle condition.

TEMPERATURE RESPONSIVE VARIABLE MEANS FOR CONTROLLING FLOW IN TURBOMACHINES (2,980,394) 4 CLAIMS Beb H. Rowlett, Playa Del Rey, and Alexander Silver, Tarzana, Calif., assignors to The Garrett Corporation, Los Angeles, Calif. A specific application of the temperature responsive variable means is an aircraft cabin cooling turbine driven by compressed air bled from the compressor of the aircraft engine. When the aircraft engine is operating at a varying power output, the bleed air flow through the cooling turbine is continually controlled by a temperature responsive variable means. The temperature responsive means will operate the cooling turbine at the desired refrigeration output while utilizing a minimum amount of compressed air, thus conserving power of the aircraft engine furnishing the compressed air.

(Continued on page 39)

DUCTED FAN FLAMEHOLDER (2,979,900) 6 CLAIMS Philip S. Hopper, Manchester, Conn., assignor to United Aircraft Corporation, East Hartford, Conn. Flameholder construction in which combustion is supported in both a stream of heated gas and a stream of cold air carrying a fuel having poor low temperature vaporization characteristics. Flameholder unit 40 includes a plurality of annular flameholder rings 56, 58, 60 and 62. The flameholder rings are coaxial and concentrically located about axis 54 and are of trough or U-shaped cross section opening in a downstream direction. The flameholder rings are spaced axially with respect to each other and each is positioned to be radially perpendicular to axis 54. Flameholder ring 56 will intercept the cold or low temperature gas-fuel mixture passing through gas passage 46, flameholders 60 and 62 will intercept the heated or high temperature gas-fuel mixture passing through gas passage 32 and because flameholder ring 58 is positioned immediately downstream of and in substantial axial alignment with the after end 64 of splitter duct 34, to which it is attached, flameholder ring 58 will intercept both the cold gas-fuel mixture of gas passage 46 and the heated gas-fuel mixture of gas passage 32.



PATENTS . . .

(Continued from page 36)

ADJUSTABLE BLADING FOR FLUID FLOW MACHINES (2,985,427) 5 CLAIMS Warren Houghton, Manchester, Mass., assignor to General Electric Co. Adjustable blade which provides a reduced variation in clearance between an edge of the blade and an adjacent rotor.

PRESSURE RATIO COMPUTER (2,979,895) 14 CLAIMS Elmer A. Haase and Wayne E. Werts, South Bend, Ind., assignors to The Bendix Corp. A device for controlling the fuel flow to a gas turbine engine so that optimum engine acceleration may be obtained throughout the speed range of the engine.

AFTERBURNER CONTROL FOR A MULTISPOOL GAS TURBINE POWER PLANT (2,984,969) 8 CLAIMS Bruce N. Torell, Wethersfield, Conn., assignor to United Aircraft Corp., East Hartford, Conn. One object of the invention is to provide an afterburner control for multispool gas turbine power plant which enables operation of the power plant during partial afterburning without changing spool speed or air flow through the power plant.

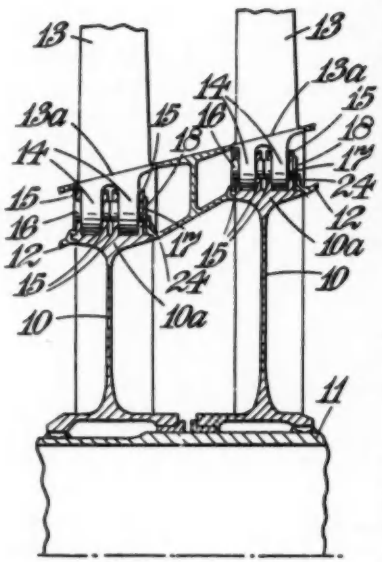
STATOR CONSTRUCTION FOR TURBINE ENGINES (2,980,396) 7 CLAIMS Edward N. Movesian, Stoneham, Mass., assignor to General Electric Co. Improved stator construction in which segmented arcuate guide vane assemblies may be easily and rapidly assembled and disassembled in grooved rabbets of an integral annular casing.

MULTIPLE PRESSURE SENSING, INDICATING AND CONTROL APPARATUS (2,981,058) 5 CLAIMS Wendell E. Reed, Chula Vista, Calif., assignor to Solar Aircraft Company, San Diego, Calif. Provides novel pressure responsive units for sensing, indicating or controlling one or more quantities or conditions of a fluid flow system and novel control systems utilizing these units.

ROTOR WITH PIVOTED BLADES FOR COMPRESSORS AND TURBINES (2,980,395) 15 CLAIMS Arthur A. Rubbra, Littleover, and Ronald Jones, Derby, England, assignors to Rolls-Royce Limited, Derby, England. Each blade element 13 of the stage of rotor blading is formed at its inner end with a blade platform 13a from which the operative portion of the blade extends and from the underside of which extend a pair of axially-spaced radially-extending lugs or flanges 14 having aligned bores therein.

The periphery 10a of the disc 10 is axially thickened and is provided with four axially-spaced, radially-extending peripheral flanges 15, the spacing of the upstream pair of flanges 15 being equal to the axial thickness of the upstream lug or flange 14 of a blade element 13 and the axial spacing of the downstream pair of flanges 15 being equal to the axial thickness of the downstream lug or flange 14 of the blade element 13.

Each blade element 13 is held in position on the disc periphery 10a with the bores in its lugs or flanges 14 aligned with the corresponding set of bores in the flanges 15 by a pivot pin assembly which in effect comprises an individual pivot pin element for each lug or flange 14. Each pivot pin element is thus engaged with a pair of flanges 15 and one lug or flange 14. The pivot pin elements 16, 17 are arranged so that they can move rotationally relative to one another and this arrangement reduces wear on the pivot pin elements.



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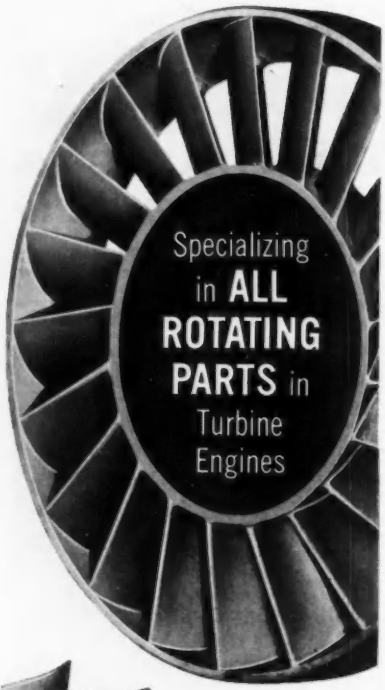

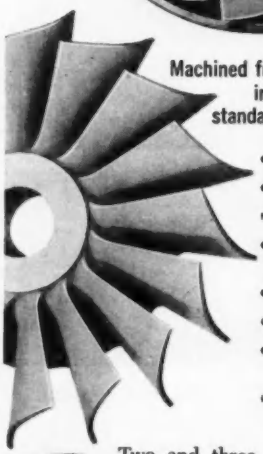

Machined from the solid in exotics and standard materials:

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- Shrouded Impellers
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GT PRODUCT TECHNICAL FILE

Synchro-Start Catalog

"In 1932 Syncro-Start originated the concept of an automatic control system which made it possible to start and stop internal combustion engines without the presence of an attendant. They have proven their dependability and long life over a period of many years."

(signed by)
Wm. J. Williams, President

This is the first paragraph in the 1961 catalog which covers the complete line made by Syncro-Start Products. It is not every year this fine very elaborate catalog comes out (this is the 6th since 1932).

933

Keeping Pace With Progress

Several new brochures are now available from Chandler Evans Corp., not only covering their long line of control equipment but also other products and manufacturing and testing facilities. Chandler Evans is not only "keeping pace with aircraft progress" but are deep into both space and industrial equipment as shown by their new brochures.

934

New Marman Booklet

A new booklet entitled "How. When and Why to use a V-Band Coupling" is now available. This booklet was produced by the Marman Division of Aeroquip Corporation. It explains how the simplified fastening of the V-Band Coupling can improve functional design and product appearance, decrease assembly time and cut manufacturing costs.

935

The Austin 250

An 8-page brochure is now available describing the single-shaft Austin 250, 250-hp gas turbine for industrial use. Built by Austin Motor Co. of England, one of the first to sell for less than $30 per hp.

936

Continental Brochures

Gas Turbine brochures are now available from Continental Aviation & Engineering Corp.

Continental 142-1, a truly versatile engine, provides both shaft hp and compressed air, either simultaneously or independently, up to 350-hp.

Continental 141 gas turbine air compressor delivers up to 191 air hp on a standard day. When the 141 is equipped with a front end gear box with main output shaft it becomes a model 142-1.

Continental-Turbomeca 261-4 (Turmo III-C) rated 1065-hp, take off 1184-hp. The output shaft is driven by a separate power turbine.

Continental-Turbomeca single shaft units now available through Continental are:

Model 220-5 (Artouste II-C) rated 330 hp, take-off 400 hp.

Model 231-2 (Astazou II) rated 473 hp, take-off 522 hp.

Model 235-4 (Baston IV) rated 789 hp, take-off 916 hp.

937

First International Symposium on Gas-Lubricated Bearings

Sponsored by the Office of Naval Research and conducted by the Franklin Institute, this Symposium was held on an international basis in Washington, D. C., on October 26-28, 1959. Presenting an introductory overall examination and critical review of research and development pertinent to gas-lubricated bearings design technology, the Symposium served as a meeting place for the presentation of papers by scientists from the United States and eight foreign countries. This 617-page volume records the twenty technical papers presented at the Symposium, in their entirety, as well as a final panel discussion. A bibliography of some 290 entries appears as an appendix in this volume.

938

Nugent Product Index

Bulletin A recently made available by Wm. W. Nugent & Co. is an index of individual bulletins illustrating and describing the complete Nugent line of products for lubrication systems including their well-known filters.

This very complete 6-page publication should be in your files for reference whenever data is needed on lube systems or filtration.

939

Johnson Bronze Has New Sleeve Bearing Brochure

In a 4-page color brochure, Johnson Bronze Company describes their custom-designed and standard stock sleeve bearings and bar stock line. Solid bearings are available in bronze and aluminum. Those in bronze may be cast, rolled or made of powdered bronze. In addition there is a complete line of bronze or steel-backed bearings with babbitt, copper-lead and on the steel backs, aluminum overlays.

The brochure also gives information on Johnson's research center and the company's technical service. Bearing design problems are invited.

940

Jet Analyzer Described

Howell Instruments, Inc. has two new brochures dealing with testers for jets and other gas turbines. The first deals with the Jetcal Tester that was designed originally to functionally test thermocouple systems of jet aircraft.

The second, on the Jetcal Analyzer, allows the mechanic to trouble-shoot the thermocouple system and also has an rpm check circuit for testing the tachometer system. With it, tabbing and/or setting of jet engine controls is aided. Tailpipe temperature can be set within ±4° C and rpm within ±0.1% rpm.

941

Snap-Tite Coupling Catalog

"Simplified selection of quick-connect/disconnect couplings" is stated as the purpose of this 62-page catalog from Snap-Tite, Inc. They say that with over 500,000 different combinations available to coupling users, a product selector is a must.

Construction details, materials, dimension and weight data, and operating data such as working pressures, flow, pressure drop and spillage data are given for the product line in such a way that a sound choice can be made with ease.

942

"The Hopkins Process"

This brochure and others are available from Firth Sterling illustrating metals made specifically for many leading gas turbine builders. The Hopkins Process is "the modern technique for producing high purity metals."

The following are among the High Temperature Alloys produced by Firth Sterling:

A-286
Greek Ascoloy
16-25-6
N-155
V-57
901
Waspaloy
And to a lesser extent:
M-252
Udimet 500
Rene 41
Consumably Melted
300 and 400 series stainless

943

Cooper-Bessemer's All-Products Bulletin

Here's a 14-pager in four colors that covers Cooper-Bessemer's full product line. Along with the products, applications are detailed.

Of particular interest here are the listings on centrifugal compressors, industrial jet-powered turbines and their En-Tronic Control systems, all currently being used in gas transmission, chemical and petrochemical processing and other industrial applications.

Also, the booklet tells where branch and subsidiary offices are located and outline's the company's unique on-the-spot field, warehouse and engineering services.

944

Correction on Centrax Heat Exchanger

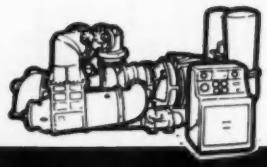
Last issue, referring to Centrax' new brochure, we mentioned dropping the SFC of 2500-hp gas turbine from 0.9-lb/hp/hr to under 0.6. It should have read "*the SFC of 500-hp gas turbine*".

Don't let these Devils INTERFERE
with OPERATING
PERFORMANCE
CROSS-PULL
WEAR
IMPACT
DOWNTIME
BACKLASH
Troublesome maintenance and lubricating problems are eliminated when you specify Thomas "All-Metal" Flexible Couplings to protect your equipment and extend the life of your machines.
Like a thief in the night an inadequate coupling causes wear and damage to your machines — resulting in high maintenance costs and costly shut-downs.
UNDER LOAD and MISALIGNMENT only THOMAS FLEXIBLE COUPLINGS offer all these advantages:
• Freedom from Backlash
• Torsional Rigidity • Free End Float
• Smooth Continuous Drive with Constant Rotational Velocity
• Visual Inspection while in Operation
• Original Balance for Life
• Unaffected by High or Low Temperatures
• No Lubrication • No Wearing Parts
• No Maintenance
THOMAS
FLEXIBLE COUPLINGS
Write for Our New Engineering Catalog 60
THOMAS FLEXIBLE COUPLING COMPANY
WARREN, PENNSYLVANIA, U.S.A.

For more information write in No. 919

He's testing the 109th

...just part of routine in the flow of Ruston TA Gas Turbine production, but it's worth noting that over *one hundred* TA's have been dispatched from our Works... and they all receive the same meticulous attention throughout production and individual test. It is also significant that of the continuous-service industrial gas turbines in the 1000/2000 b.h.p. bracket, easily the greatest number now operating throughout the world are Ruston TA's.



RUSTON

'TA' GAS TURBINES

The lightweight, long-life power units which give 1260 b.h.p. at the push of a button — and regularly over 10,000 hours between inspections.

RUSTON & HORNSBY LTD · LINCOLN
Associated with Davey Paxman & Co. Ltd., Colchester

For more information write in No. 914

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Ever Wonder **HOW?** A Speed Switch Works

Three industrious little elements doing the work of 6 is the answer. Ask for Speed Sensitive Switch Bulletin 604.

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Since 1932
8151 NORTH RIDGEWAY AVENUE • SKOKIE, ILLINOIS

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SEVENTH ANNUAL

GAS TURBINE CONFERENCE and PRODUCTS SHOW

7

MARCH 5-8, 1962

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SPECIAL ANNOUNCEMENT

ANNUAL
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PROCESS INDUSTRIES
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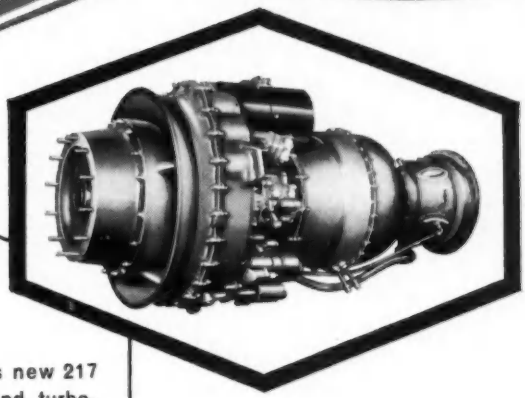
Will Meet at the
Same Time and Place

The CONTINENTAL 217 ... USE-PROVED AIRCRAFT POWER



Behind Continental's new 217 series of turboshaft and turboprop engines for business and utility aircraft is a truly impressive record of military service. For the 217 has evolved directly from the highly successful J69, power plant of the Cessna T-37 Trainer and the Q-2C Target Missile, which has withstood 40,000 test stand hours, and more than a million hours in flight.

Model 217-5A has 6000-rpm output shaft, Model 217-6A has 2100-rpm flanged propeller shaft drive. Both versions combine high performance and operating economy with long life, low weight, LOW INSTALLED COST.

PERFORMANCE

500 SHP, with high economy (0.67 SFC).

RELIABILITY

Simple, rugged design . . . Foreign-object-tolerant all-steel rotating system . . . Anti-icing inlet . . . Fail-safe dual element fuel pump . . . Trouble-free fuel distribution system . . . Emergency fuel circuit with manual controls.

INSTALLATION ADVANTAGES

Compactness (19-in. overall diam., 42-in. overall length) . . . Straight-out rear exhaust—no obstructions or turns . . . Front power output on engine center line . . . Front reduction gear surrounded by cool air . . . High accessibility—all accessories mounted around waist . . . Optional mounting: single plane, two-plane, or cantilever . . . Low weight (245 lbs.).

FOR DETAILED INFORMATION, ADDRESS:

CONTINENTAL AVIATION AND ENGINEERING CORPORATION
12700 KERCHEVAL AVENUE, DETROIT 15, MICHIGAN
SUBSIDIARY OF CONTINENTAL MOTORS CORPORATION

WESTERN SALES OFFICE: 18747 SHERMAN WAY, RESEDA, CALIFORNIA

For more information write in No. 916

What do you like best about BENDIX CONTROL SYSTEMS for small gas turbines?

"They are light, rugged and dependable."

"Simple design saves cost and space."

"The engineering and service are the best."

Bendix control systems rate first among turbine engine designers and users because they know these systems are performance-proved for reliability and economy. They know, too, that whatever the small gas turbine engine problem, Bendix has the know-how to tailor a control system to their needs.

When you buy Bendix, you buy quality products backed by over 30 years of fuel metering experience and the best service coverage available. If you have a requirement for control systems for small gas turbines, write: Sales Manager, Propulsion Controls, Bendix Products Division, South Bend, Indiana.

Bendix PRODUCTS DIVISION South Bend, IND.

THE Bendix CORPORATION

For more information write in No. 917